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Contents of previous issues of the JOURNAL OF ANIMAL SCIENCE are indexed in the Agricultural Index which is available in most libraries and in the November issue of each complete volume of the JOURNAL.

THE SERUM PROTEIN-BOUND IODINE OF SWINE AS A MEASURE OF GROWTH POTENTIALITIES [1]

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ACCURATE, but simple chemical methods for ascertaining potentialities for growth and for other major genetically controlled physiological changes in farm animals have been receiving due attention in recent years. Certain biochemical changes, the magnitude of which can be accurately determined and correlated with easily measured anatomical changes, could be utilized for this purpose.

There are indications that the level of protein-bound iodine (PBI) in the blood and average daily gain may bear a relationship.

Kunkel (1953) suggested that the level of serum protein-bound iodine (PBI) may be used as a partial index of the potential efficiency of feed utilization or of the potential feed lot gain in immature beef cattle. There was an optimum level of protein-bound iodine which was related to maximum weight gains; whereas above and below this level the gains were less.

That there were definite advantages in the utilization of the PBI level in the serum over the basal metabolic rate as a measurement of thyroid activity was suggested by Rapport (1950). The latter measures the oxygen consumption by the individual which is the end result of all the oxidative processes of the body. This rate of oxygen consumption may or may not be related to the transport, utilization, and breakdown of the thyroid hormone.

In the report of Long (1952) it was shown that the PBI value was affected by the breed of the cattle. Long reports that the breeds ranked from high to low, as follows, with regard to their average PBI, given in gamma percent: Jersey (4.11), Guernsey (3.51), Brown Swiss (3.37), Ayrshire (2.19), Holstein (2.73), and beef breeds (2.19). Blincoe and Brody (1951) found that the PBI range in Brown Swiss and Brahman heifers did not differ.

To date the literature contains no report of investigations of serum PBI levels and growth in immature swine. It is the purpose of this paper to report the result of a study of the serum PBI levels of a

[1] The material in this paper is a portion of that submitted in thesis form for the M.S. degree. Missouri Agricultural Experiment Station, Journal Series No. 1457.

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single breed of swine. The PBI values obtained were correlated with average daily gain and with observable anatomical changes including back fat thickness, length of left hind leg, and body length.

Methods and Experimental

Young purebred Hampshire gilts and barrows, grown to a two hundred and fifteen lb. weight level before being slaughtered, were used in the present investigation.

The majority of the blood samples for the PBI determinations, (in micrograms per 100 ml.) was collected at the time of slaughter; but a few were collected prior to slaughter by slitting the tail of the animal.

The method used for the serum PBI determinations was essentially the alkaline ash method described by Salter and Rosenblum (1951) with minor alterations in procedure which eliminated loss of material during the early stages of the procedure. Two blanks were run with every group of eight determinations as a check on contamination of the samples.

The average daily gain, back fat thickness, length of left hind leg and body length were recorded at slaughter, and the relationship of these measurements with blood PBI levels were analyzed statistically.

Results and Discussion

The gilts and barrows from which the blood specimens were obtained had been divided into experimental groups of six animals each. One group was full-fed whereas the other three groups were limited fed at 65, 75, and 85 percent of the feed intake of the full-fed group. Since the data showed no significant differences between these groups in serum PBI levels and their relationship to the body measurements previously enumerated, these animals have been treated as one experimental group in the data presented in table 1. These data show the PBI values in the blood serum of the Hampshire gilts and barrows studied. The range in PBI was 1.2 to 5.4 mcg. per 100 ml. of serum with an average value of 3.08 mcg. per. 100 ml. of serum. Although the data suggest no difference in the PBI due to sex; these data are too limited in number to make any definite conclusion.

The results, although limited in quantity, indicate several trends in the various relationships studied.

A significant linear correlation between the average daily gain (table 1) and the serum protein-bound iodine level was obtained ($r = -0.602$;

p less than 0.01). These results support the theory that the level of serum protein-bound iodine may be used as a partial index of potential gain in young swine. The protein-bound iodine values increased as the average daily gains in pounds decreased.

The linear correlation between the protein-bound iodine level in the serum and left hind leg length was not significant, but suggested that as the PBI level increased the leg length also increased.

TABLE 1.

Swine No.	Sex	Mcg. of Iodine per 100 ml. (Av. of Duplicates)	Av. Daily Gain in lbs. per Day	Body Length, mm.
142	♀	1.2	1.52	720
70	♀	1.2	1.29	770
63	♀	1.4	1.30	735
90–10	♂	1.6	1.36	759
20	♀	1.7	1.24	saved
73	♂	1.7	1.06	736
31	♀	1.8	1.47	766
130	♀	2.0	1.44	730
40	♀	2.6	0.86	697
122	♂	2.8	1.23	710
50	♀	3.1	1.13	724
41	♂	3.1	1.03	700
81	♂	3.3	0.84	733
113	♂	3.4	1.12	720
64	♀	3.5	1.08	716
92	♀	3.9	1.52	714
144	♀	3.9	0.82	708
121	♀	4.5	0.85	710
60	♂	5.1	0.91	720
102	♂	5.4	0.96	728

Interestingly, a significant correlation between PBI level and fat back thickness was not obtained in this investigation.

The results suggested that the protein-bound iodine of the serum increased as the body length decreased. The linear correlation between these two values was significant ($r = -0.516$; p less than 0.05).

It is suggested by the authors that more data on the relationship between body length and thyroid activity in swine as measured by blood PBI levels would be of value and that this relationship may prove to be statistically significant.

It may become possible by determining the protein-bound iodine level in the blood of young swine to predict whether they will be good

gainers or not. The body length and hind leg length, as possible morphological indicators of blood PBI levels, may be used as indicators either for the use of thyro-protein or of thiourocil therapy and dosage.

Summary

1. The average protein-bound iodine values of Hampshire gilts and barrows was 3.08 mcg. per 100 ml. of serum. The range was 1.2 to 5.4 mcg. per 100 ml.

2. The average daily gains of the young Hampshire swine studied increased as the level of PBI decreased (p less than .01).

3. The body length decreased as the PBI levels in the blood increased (p less than 0.05).

4. Individual pigs with longer left legs also tended to have a higher PBI content in the blood but the correlation was not statistically significant.

5. The average back fat thickness increased as the PBI level decreased. The linear correlation was not significant, however.

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SOME EFFECTS OF PURIFIED ANTERIOR PITUITARY GROWTH HORMONE ON SWINE [1, 2]

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THE processes of growth and fattening are of fundamental importance to the livestock producer. One of the objectives in cattle and sheep production is to increase fat deposition in the young animal in order that satisfactorily finished carcasses can be produced at an early age. Swine, on the other hand, are unique in that fat deposition increases at a very early age and overshadows muscular growth by five or six months of age. Several decades of selection of swine for rapid gains, and economic conditions favoring the conversion of feedstuffs to animal fat have resulted in the production of many excessively fat hogs. In recent years the reduced demand for lard, and the increasing consumer preference for leaner pork cuts have emphasized the desirability of reducing fat deposition in hogs, and increasing muscular growth.

The primary regulating agent for muscular and skeletal growth is the anterior pituitary growth hormone. It would appear that continued selection of swine for early fattening may have affected the production and/or the utilization of the growth hormone.

The objectives of this study were to investigate the effects of daily injections of a purified growth hormone preparation on rate of gain, feed utilization, feed efficiency, and carcass composition of swine.

Experimental

Three trials were conducted. Barrows weighing 100–115 lb. were housed in adjacent individual concrete pens. They were self fed a complete mixed ration containing approximately 16 percent crude protein until they weighed 150 pounds, and approximately 14 percent crude protein for the remainder of the trial (table 1). Water was avail-

[1] Contribution from the Department of Animal Husbandry, Journal Paper No. 802, Purdue University Agricultural Experiment Station in cooperation with the Regional Swine Breeding Laboratory, Ames, Iowa, Bureau of Animal Industry, U.S.D.A.

[2] A portion of the thesis presented to the Graduate Faculty at Purdue University by the senior author in partial fulfillment of the requirements for the degree of Doctor of Philosophy, August 1953.

[3] The authors express their appreciation to Dr. Irby Bunding, The Armour Laboratories, Chicago, Illinois for the purified growth hormone.

TABLE 1. COMPOSITION OF RATIONS

Ingredient			16% Crude Protein	14% Crude Protein
			(%)	(%)
Ground yellow corn			75.65	81.05
Purdue Supplement 5			22.10	16.70
Soybean oil meal	40			
Fish meal	20			
Meat and bone scraps		20		
Cottonseed meal		10		
Alfalfa meal		10		
Mineral mixture			1.50	1.50
Ground limestone		40		
Steamed bone meal		40		
Iodized salt		20		
Concentrated cod-liver oil			0.25	0.25
Vitamin B_{12}—Antibiotic supplement			0.50	0.50

The above ration was fortified with the following vitamins per 100 pounds of mixed feed: 80 mg. riboflavin, 450 mg. calcium pantothenate, and 500 mg. niacin.

able at all times. Individual body weights and feed consumption were determined at weekly intervals. Individual animals were slaughtered when they reached a body weight of approximately 220 lb.

At the time of slaughter the conventional carcass data shown in table 2 were collected, and the right half of each carcass was completely

TABLE 2. THE EFFECT OF DAILY INJECTIONS OF PURIFIED GROWTH HORMONE ON DAILY GAIN, FEED CONSUMPTION AND FEED EFFICIENCY OF SWINE

Trial	Treatment	No. Pigs	Days on Trial	Av. Initial Wt. lb.	Av. Final Wt. lb.	Av. Daily Gain lb.	Av. Daily Feed lb.	Feed per 100 Lb. Gain lb.
1	Uninjected control	2	55	115.0	230.5	2.10	8.24	392
	5 mg. g.h./15 kg./day	1	60	116.0	233.0	1.95	6.52	337
	10 mg. g.h./15 kg./day	1	60	114.0	232.0	1.97	6.13	311
2	Saline injected control	3	47	111.0	220.0	2.32	8.64	373
	2.25 mg. g.h./15 kg./day	2	44	112.5	220.0	2.56	8.00	313
3	Saline injected controls	2	51	106.0	213.5	2.11	8.26	392
	3.0 mg. g.h./15 kg./day	2	43	103.5	211.5	2.54	7.23	285*
	4.5 mg. g.h./15 kg./day	1	56	95.0	209.0	2.04	6.64	326
All Trials								
	Control	7	51	110.6	221.3	2.19	8.40	384
	Growth hormone injected	7	50	106.7	219.6	2.26	7.03**	310**

* P less than .05
** P less than .01

skinned and boned, the edible meat ground in a sausage grinder and thoroughly mixed. A sample of approximately two pounds was taken, frozen, and stored in a freezer at a temperature of approximately 2° F. until chemical determinations of protein, fat and moisture could be made. The analytical procedures followed were those outlined by the Association of Official Agricultural Chemists (1950).

The pituitary glands were obtained at the time of slaughter, the anterior lobe carefully removed, weighed on a torsion balance, and frozen until time of assay for thyrotropic and gonatotropic hormone potency. Assay was carried out with day old male White Leghorn chicks according to the methods of Bergman and Turner (1939), and of Elijah and Turner (1942).

The purified growth hormone used in these experiments was prepared by the method of Wilhelmi *et al.* (1948). The hormone dissolved in sterile saline, was administered daily in single intramuscular injections throughout the experiment. Daily doses of the growth hormone preparation used in the three trials are expressed in mg. of growth hormone in terms of the Armour standard growth hormone preparation, 22KR2. Suitable aseptic precautions were taken to minimize dangers of infection. In Trials 2 and 3 the control animals were injected daily with sterile saline in order to simulate all experimental procedures as closely as possible.

Trial 1

Four crossline barrows, Landrace-Large Black X Chester White (Purdue White King line), weighing approximately 115 lb. each, were started on experiment in January, 1952. They were fed to a final weight of approximately 230 lb. Two pigs served as uninjected controls, one barrow was injected daily with 10 mg. of purified growth hormone per 15 kg. of body weight, and one barrow received daily injections of 5.0 mg. of purified growth hormone per 15 kg. of body weight. The purified growth hormone was Armour's lot number K45408R, with a thyrotropic hormone contamination of approximately 0.5 U.S.P.–TSH units per mg.

Trial 2

Seven crossline barrows, Poland China (Missouri line VI) X Chester White (Purdue White King line), were started on experiment in August, 1952, at an average initial weight of 111 lb., and maintained on experiment to an average weight of 220 lb. Three barrows served as controls and were injected daily with sterile saline. Two barrows

received daily injections of 4.5 mg. of purified growth hormone per 15 kg. body weight, and two barrows received 2.25 mg. of growth hormone per 15 kg. of body weight per day. The purified growth hormone used was Armour's lot number GH–3, which had a thyrotropic hormone contamination of approximately 0.3 U.S.P.–TSH units per mg.

During the course of the experiment, the two pigs receiving the higher level of growth hormone died. Consequently, growth and feed consumption data and carcass data were obtained only on the control pigs and those receiving the lower level of growth hormone.

Trial 3

Seven Spotted Poland China barrows weighing approximately 100 lb. each were placed on experiment in April, 1953, and were carried to an average final weight of 212 lb. Two pigs served as saline injected controls, two pigs were injected daily with 6.0 mg. of purified growth hormone per 15 kg. of body weight, and two pigs were injected daily with 3.0 mg. of purified growth hormone per 15 kg. of body weight. The purified growth hormone used was Armour's lot number R491024, which had a thyrotropic hormone contamination of approximately 0.5 U.S.P.–TSH unit per mg. One additional pig used in the trial received the same hormone treatment as that in which two pigs died in Trial 2, i.e. 4.5 mg. of growth hormone (lot GH–3) per 15 kg. of body weight per day. No growth or carcass data were obtained on the pigs receiving 6.0 mg. growth hormone in Trial 3 since both died.

Determinations were made of blood levels of inorganic phosphorus, glucose and non-protein nitrogen in Trial 3. Pigs were fasted for 12–14 hours prior to bleeding from the anterior vena cava. All pigs were bled at the beginning of the experiment, and at two week intervals thereafter. All chemical determinations were made on whole blood collected in oxalated tubes. Inorganic phosphorus was determined by the method of Fiske and SubbaRow, as outlined by Hawk *et al.* (1947), with the dilution modified for use with the Evelyn photoelectric colorimeter. Non-protein nitrogen was determined by the Method of Folin and Wu as described by Hawk *et al.* (1947). Blood glucose was determined by the micro technique of Folin (1929).

Results

Weight gain and feed data are presented in table 2, and carcass data in table 3. The data for all trials were combined for purposes of statistical analysis (table 6). The variances for each of the three trials

were tested for homogeneity by Bartlett's tests of homogeneity of variances, as outlined by Snedecor (1946). The probability values obtained in these tests were not significant.

Rate of Gain

Pigs receiving growth hormone gained faster than the controls in Trials 2 and 3 (table 2). In Trial 1 the controls did not receive daily injections of sterile saline, which may account for their slightly faster gains. The differences were not statistically significant.

Feed Consumption and Efficiency

There were highly significant differences (P less than .01) in daily feed consumption and the amount of feed required per 100 pounds gain (table 2). In all trials the average daily feed consumption of the pigs which were injected with growth hormone was 7.03 lb., and that of the controls was 8.40 lb. per day. Growth hormone injected pigs required 310 lb. of feed per 100 lb. gain as compared to 384 lb. of feed for the controls.

Carcass Data

Hogs receiving growth hormone had a lower dressing percent than did the controls. There was relatively no difference in length of hind leg, but highly significant differences (P less than .01) in body length and backfat thickness (table 3). Pigs receiving growth hormone yielded carcasses with an average length of 30.6 inches, while the control carcasses averaged 29.3 inches. The average backfat thickness of hogs injected daily with growth hormone was 1.40 inches compared to 1.77 inches for the controls.

Carcass Composition

Analysis of the edible meat from one half of each carcass revealed highly significant differences (P less than .01) in content of protein, moisture and fat (table 3). The average chemical composition of the carcasses of pigs receiving growth hormone was: protein, 13.5 percent, moisture 49.1 percent, and fat 36.8 percent. The average for carcasses from the control pigs was: protein 10.8 percent, moisture 39.4 percent, and fat, 49.3 percent.

Assay of the Anterior Pituitary Glands

The results of the chick assays for gonadotropic and thyrotropic hormone concentration of the pituitaries are presented in table 4. The

TABLE 3. THE EFFECT OF DAILY INJECTIONS OF PURIFIED GROWTH HORMONE ON THE CARCASS COMPOSITION OF SWINE

Trial	Treatment	No. Pigs	Live Wt.	Chilled Carcass Wt.	Carcass Measurements: Dress. Percent	Hind Leg Length	Body Length	Av. Back fat Thickness	Chemical Composition: Protein	Moisture	Fat
			(lb.)	(lb.)	(%)	(in.)	(in.)	(in.)	(%)	(%)	(%)
I	Uninjected control	2	226.0	166.0	73.5	20.8	30.0	1.91	10.9	38.8	49.8
	Growth hormone 10 mg./15 kg./day	1	219.0	154.8	70.7	21.2	30.9	1.63	14.6	53.6	30.8
	Growth hormone 5.0 mg./15 kg./day	1	222.0	157.4	70.9	21.9	31.5	1.47	13.5	46.5	39.3
II	Saline injected Controls	3	219.7	157.3	71.6	21.2	29.6	1.67	11.0	40.4	48.3
	Growth hormone 2.25 mg./15 kg./day	2	215.0	143.0	66.5	20.7	31.0	1.37*	13.0	47.8	38.8
III	Saline injected Controls	2	212.5	156.1	73.5	19.4	28.3	1.78	10.3	38.6	50.3
	Growth hormone 3.0 mg./15 kg./day	2	201.0[1]	146.8[1]	73.0[1]	20.5	30.1	1.31*	13.9	49.6*	36.0*
	Growth hormone 4.5 mg./15 kg./day	1	210.0	146.1	69.5	20.8	29.3	1.38	12.7	49.1	37.7
All Trials	Control	7	219.4	166.0	72.7*	20.5	29.3	1.77**	10.8	39.4	49.3**
	Growth hormone	7	213.0	148.5	69.5	20.9	30.6**	1.40	13.5**	49.1**	36.8

* P less than .05
** P less than .01
[1] Data on one animal only.

anterior pituitaries from pigs injected daily with growth hormone had a greater content of thyrotropic hormone than did pituitaries of the controls. In Trial 1 the differences were highly significant (P less than .01), and in Trial 2 they were significant (P less than .05). The pituitaries of growth hormone injected pigs also had a larger content of gonadotropic hormone than did the control pituitaries. The difference was highly significant in Trial 1 (P less than .01), and significant in Trial 2 (P less than .05).

TABLE 4. CHICK ASSAY FOR THYROTROPIC AND GONADOTROPIC HORMONE CONTENT OF SWINE PITUITARIES

Treatment of Chicks	Weights (mg.)	
	Chick Thyroids	Chick Testes
Trial 1		
Uninjected controls	4.1	10.0
Injected chicks—pituitaries from:		
Growth hormone pigs	7.3**	24.5**
Control pigs	3.9	17.1
Trial 2		
Uninjected controls	6.1	15.3
Injected chicks—pituitaries from:		
Growth hormone pigs	8.7*	31.4*
Control pigs	7.8	26.1

* P less than .05
** P less than .01

Glucose

The initial levels of blood glucose were comparable in all pigs, ranging from 90.0 to 97.3 mg. percent (table 5). Within one week after the initiation of growth hormone injections, blood glucose levels had increased markedly. The average blood glucose level of pigs receiving daily injections of 3.0 mg. of growth hormone (lot R491024) per kg. of body weight was 123.9 mg. percent. Saline injected control pigs had an average level of 86.3 mg. percent. The difference was statistically significant (P less than .05). A slight hyperglycemia, an average of 109.6 mg. percent for the injection period, was observed in the pig receiving 4.5 mg. of growth hormone (lot GH–3) per 15 kg. of body weight per day. The level at the end of the first week was 121.5 mg percent, but declined as treatment progressed.

Non-Protein Nitrogen

The pretreatment blood levels of non-protein nitrogen were comparable in all three groups (table 5). There was an immediate drop in NPN levels following growth hormone injection. However, the average blood NPN for the entire period of growth hormone treatment was not significantly reduced. Pigs treated for six weeks with daily

TABLE 5. THE EFFECT OF DAILY INJECTIONS OF PURIFIED GROWTH HORMONE ON LEVELS OF GLUCOSE, NON-PROTEIN NITROGEN AND INORGANIC PHOSPHORUS IN THE BLOOD OF SWINE

Treatment	Week of Treatment								Av. for Inj. Period
	0	1	2	3	4	5	6	7	
	Glucose (mg. glucose/100 ml. blood)								
Control	94.3	93.6	74.5	81.0	95.0	82.5	82.5	82.0	86.3
3.0 mg. growth hormone per 15 kg./day	90.0	127.3	129.5	116.3	116.0	122.0	129.0	....	123.9*
4.5 mg. growth hormone per 15 kg./day	97.3	121.5	....	107.0	....	104.0	....	106.0	109.6
	Non-Protein Nitrogen (mg. NPN/100 ml. blood)								
Control	55.2	57.8	57.0	54.3	56.7	....	45.0	50.3	54.1
3.0 mg. growth hormone per 15 kg./day	51.6	44.6	48.8	45.3	50.0	35.3	53.1	....	45.9
4.5 mg. growth hormone per 15 kg./day	54.6	44.7	....	36.0	....	47.8	....	50.6	44.8
	Inorganic Phosphorus (mg. inorganic P/100 ml. blood)								
Control	8.8	8.9	8.4	7.6	7.6	6.1	5.5	5.1	7.1
3.0 mg. growth hormone per 15 kg./day	8.5	8.6	8.9	8.0	8.4	6.7	5.9	....	7.7
4.5 mg. growth hormone per 15 kg./day	8.3	8.8	....	7.1	....	7.0	....	5.7	7.2

* P less than .05

injections of 3.0 mg. of growth hormone (lot R491024) per 15 kg. of body weight had an average of 45.9 mg. of NPN per 100 ml. of blood. The pig injected daily with 4.5 mg. of growth hormone (lot GH–3) per 15 kg. of body weight had an average level of 44.8 mg. percent, while the saline injected controls averaged 54.1 mg. of NPN per 100 ml. of blood.

Inorganic Phosphorus

The most marked change noted was the decline in blood inorganic phosphorus with increasing age in all groups (table 5). Pigs injected daily with growth hormone had higher levels of inorganic phosphorus than did the controls, but the differences were not significant. Blood

inorganic phosphorus levels of 7.7 mg. percent and 7.2 mg. percent were observed in pigs receiving 3.0 mg. of growth hormone (lot R491024) and 4.5 mg. growth hormone (lot GH–3) per 15 kg. of body weight per day. The level in the control group was 7.1 mg. percent.

Discussion

It has been shown that the injection of purified anterior pituitary growth hormone produces marked alterations in the growth of small laboratory animals (Li and Evans 1947). However, relatively little work has been concerned with the role of the growth hormone in farm animals. Giles (1942) injected swine twice weekly for a period of four and one-half months with a pituitary growth hormone preparation, "phyone". He observed a slight effect on the epiphyseal cartilage, but no apparent effect on growth rate, feed efficiency, organ weights, chemical composition of the carcass, or levels of blood inorganic phosphorus. Baird *et al.* (1952) concluded that the difference in growth rate between two lines of swine was due largely to significantly different rates of growth hormone secretion as determined by pituitary assays.

Daily injections of purified growth hormone did not increase the rate of gain in this study significantly. However, chemical analyses of the carcasses revealed significantly increased nitrogen retention and a reduction in fat. Thus it appears that daily injections of purified growth hormone stimulated true growth in the swine used in these experiments.

The marked differences in feed required per unit of gain also reflects fundamental differences in the nature of the gains. Since both the control and growth hormone injected groups were on experiment approximately the same length of time, there were probably relatively negligible differences in the maintenance requirements. The differences in fat deposition contribute to the apparent decreased feed efficiency of the control swine. Baird *et al.* (1952) observed that a rapid-gaining line of hogs, whose pituitaries contained significantly more growth hormone than a slow gaining line, were also more efficient in feed utilization. It is probable, however, that this difference in feed efficiency was due to many factors, of which the relative difference in rate of growth hormone secretion may be only one.

Assays of the anterior pituitary glands revealed significant increases in the thyrotropic and gonadotropic content of the pituitaries of hogs injected daily with growth hormone. Smelser (1944) and others have presented evidence that the gonadotropic and thyrotropic hormones are

produced by the basophils of the anterior pituitary, and the growth hormone by the acidophils. Koneff *et al.* (1948) found that daily injection of growth hormone in rats for 437 days decreased both number and size of the acidophils. Their interpretation was that the injected growth hormone depressed the functional activity of the cells producing growth hormone.

The data obtained in this study indicated that both the thyrotropic and gonadotropic hormone content of the pituitaries was increased. However, direct evidence for increased output of these hormones was inconclusive. The thyroids of the growth hormone injected pigs did not show histological evidences of stimulation at the time of slaughter. The thyroids of the pigs which died during the course of treatment did show varying degrees of hyperplasia. However, the apparent hyperthyroid condition may have been the result of the thyrotropic hormone contamination of the growth hormone preparation. Since castrate hogs were used, there were no target organs available to indicate possible effects of increased gonadotropic hormone production.

Purified growth hormone has been shown to have a diabetogenic effect in a number of species. While the increases in levels of blood glucose observed in growth hormone injected pigs were significant, they were relatively slight in comparison with the hyperglycemia reported in other species. For example, Campbell *et al.* (1950) observed levels above 300 mg. percent in growth hormone injected dogs, compared to 60–68 mg. percent in uninjected controls. However, the blood glucose levels observed may be relatively high for the pig. Link (1953) reported that the renal threshold in growing pigs was 142.4 to 169.0 mg. percent of glucose.

Growth hormone injected pigs also had a lower blood level of nonprotein nitrogen, and slightly higher levels of inorganic phosphorus than did the controls. Although these differences were not significant, similar observations have been made in hypophysectomized rats (Li *et al.*, 1949) injected with growth hormone.

Marked pathological changes were observed in some of the organs of growth hormone treated pigs in Trials 2 and 3. The most pronounced changes were fatty infiltration and degeneration of the liver, and fatty albuminous degeneration of the kidneys. Four of eleven growth hormone treated pigs died during the course of the experiments. The clinical symptoms and histopathology will be described in a subsequent publication.

TABLE 6. ANALYSIS OF VARIANCE ON THE EFFECTS OF PURIFIED GROWTH HORMONE ON SWINE

Source of Variation	d.f.	Mean Squares									
		Av. Daily Gain	Daily Feed Cons.	Feed per lb. Gain	Dressing Percent	Hind Leg Length	Body Length	Backfat Thickness	Chemical Composition		
									Protein	Moisture	Fat
Treatments	1	.04	4.48**	1.90**	32.16*	.4	5.4**	3.07**	25.5**	329.3**	548.1**
Trials	2	.18	1.46	.06	11.19	1.4	2.3*	.38*	.5	3.7	8.6
Error	10	.06	0.41	.05	4.80	.5	0.5	.09	.5	5.4	9.0

* P less than .05
** P less than .01

Summary and Conclusions

Pigs injected daily with three different purified growth hormone preparations gained at a slightly, but not significantly, faster rate, consumed significantly less feed per day, and required significantly less feed per unit of gain than did non-injected pigs.

The carcasses of growth hormone injected pigs contained significantly more protein and moisture, and less fat than did the carcasses of control pigs.

Daily injections of growth hormone in swine resulted in significant increases in blood glucose, slight, but not significant, increases in blood inorganic phosphorus, and decreased blood non-protein nitrogen. The anterior pituitary glands of pigs injected daily with growth hormone contained significantly more of the thyrotropic and gonadotropic hormones than did the pituitaries of control pigs.

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A STUDY OF "GROWTH STIMULANTS" USING THE BABY PIG

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MOREHOUSE and Mayfield (1946, 1949) reported that 3-nitro-4-hydroxyphenylarsonic acid had remarkable growth stimulating properties for chickens and turkeys. This surprising finding was confirmed by Bird *et al.* (1949). Since one mode of action of the phenylarsonic acids seems to be related to an alteration in bacterial metabolism (Frost, 1953), a study on the growth stimulation of arsanilic acid (p-amino-phenylarsonic acid) using the baby pig is reported here in a study of "growth stimulants" which may be conceivably related to the antibiotics in their mechanism of action.

The growth stimulation of sulfa drugs was first reported by Moore *et al.* (1946) in chicks fed a purified diet. The work of Bauernfeind (1952) with chicks seemed to indicate it would be worthwhile studying the widely used sulfisoxazole (3,4-dimethyl-5-sulfanilamido-isoxazole) as a growth stimulant for baby pigs.

Since the addition of various surface activating agents to the ration of chicks has been reported to exert a significant effect on growth (Ely, 1951), we have studied the effect of surfactants, both singly and in combination, on the growth of baby pigs.

An antibiotic concentrate isolated by Frieden, designated as Number 802 and shown by him to be active for chicks (1951), was also studied and is reported here.

Experimental

The experimental animals chosen for these experiments were baby pigs 48 to 96 hours of age. The animals used in the antibiotic study were purebred Chester Whites, Hampshires and Duroc-Jerseys obtained from the University Swine Farm. The remaining piglets were crossbred animals procured from a commercial pig hatchery. In general, animals were assigned at random to their respective treatments, housed in raised wire-bottom cages and fed *ad libitum*. However, in experiment 3 the animals were paired with respect to litter, sex and initial weight.

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Individual feed consumption was measured and the animals were weighed at weekly intervals.

The composition of the "synthetic milk" ration, using isolated soy-bean protein supplemented with 0.6 percent DL-methionine as the source of protein, has been reported previously by Schendel and Johnson (1953). This milk, supplemented with the fat soluble vitamins A, D, E and K was made up to contain 19.5 percent solids and 6 percent fat as described by Neumann *et al.* (1950). The water soluble vitamins were administered in a 30 percent ethanol solution at the time of feeding and vitamin B_{12} was administered intramuscularly at a level of 0.8 μg. per kg. body weight per day (Nesheim *et al.* 1950). Sulfathalidine was also added at the rate of 2 gm. per liter of milk in an effort to control scouring. The method of feeding and care of baby pigs in this laboratory has been reported previously (Johnson *et al.*, 1948).

In experiment 1, the basal ration was supplemented with aqueous solutions of arsanilic acid,[2] sulfisoxazole [3] and ethomeen C/15 [4] at levels of 90, 500 and 750 mg. per kg. dry matter diet, respectively. The interactions of these treatments were also studied.

In experiment 2 a surfactant combination of arquad S at 0.5 gm. per kg. dry matter diet and ethomid C/15, ethofat C/15, aerosol CS, aerosol SE and ultrawet K each at a level of 1.0 gm. per kg. dry matter diet was added. The three main classes of detergents, cationic, anionic and nonionic, are represented in this combination, including those which are used most widely as detergents, wetting and emulsifying agents.

The antibiotic concentrate, Number 802, was provided as the treatment in experiment 3 at the level of 11 gm. per kg. dry matter diet.

Results and Discussion

A summary of the performance of the animals in these experiments appears in tables 1 and 2. Three animals died in the first week due to causes which remained obscure following post mortem examination. The stress conditions offered by the synthetic milk, etc. were apparently too severe for these, the smallest animals of the group, and they are, therefore, excluded from the tables and the analysis.

Statistical analysis of data for the animals in experiment 1, using the method of fitting constants, revealed that arsanilic acid increased

[2] Abbott Laboratories, D. V. Frost.
[3] Hoffman La Roche, Inc., J. C. Bauernfeind.
[4] Armour & Company, B. M. Shinn.

TABLE 1. EFFECT OF VARIOUS "GROWTH STIMULANTS" ON BABY PIGS

Treatment	Number of Animals	Days on Experiment	Average Total Gain	Average Dry Matter Cons.
			Kg.	Kg.
Experiment 1				
Basal	2	28	4.16	7.42
Arsanilic acid	2	28	6.16	10.90
Ethomeen C/15	1	28	5.62	10.08
Arsanilic acid and Ethomeen C/15	1	28	4.36	7.88
Arsanilic acid and Sulfisoxazole	2	28	6.89	9.67
Ethomeen C/15 and Sulfisoxazole	1	28	3.58	6.06
Arsanilic acid and Ethomeen C/15 and Sulfisoxazole	3	28	6.02	9.50
Experiment 2				
Basal	3	28	6.30	11.46
Surfactant combination	3	28	7.08	15.39
Experiment 3				
Basal	4	49	14.73	26.08
Antibiotic No. 802	4	49	17.04	31.13

TABLE 2. TISSUE ANALYSIS [1] OF BABY PIGS FED ARSANILIC ACID

Treatment	Pig Number	Dried Liver		Dried Ham	
		Evans	Frost	Evans	Frost
		P.P.M.		P.P.M.	
Basal	1	0.05	0.65		
			0.26		
			0.19		
Arsanilic acid	5	20.8	27.5	0.80	0.96
			23.6		
			26.9		
			25.0		
Arsanilic acid	6			0.60	0.61

[1] The tissue analysis data were supplied by Dr. R. F. Evans, Michigan State University, East Lansing, Michigan and Dr. D. V. Frost, Abbott Laboratories, North Chicago, Illinois.

growth significantly (P less than 0.05). The effects of ethomeen C/15 and of sufisoxazole on final weights were not significant.

Similar analysis revealed arsanilic acid significantly increased feed consumption (P less than 0.02). The interaction of arsanilic acid and sulfisoxazole also appeared significant (P less than 0.05), more feed having been consumed when both were present than could be accounted for on the basis of their separate effects. The interaction of arsanilic acid and ethomeen C/15 significantly depressed feed consumption (P less than 0.05.

The level of arsanilic acid used in this experiment was based on work done with chicks (Frost, 1953). From the analyses of two of the pigs receiving arsanilic acid (table 2), however, there is some indication that the baby pig retains roughly 3 times the amount of arsenic in the liver than chicks fed the same amount of arsanilic acid. This increased retention suggesting a possible increased toxicity, may account for the deaths of these animals in the fourth week when they were the largest pigs on experiment.

Inspection of table 1 reveals that the surfactant combination used was unable to stimulate growth beyond the basal group. This observation is in agreement with Scott and Johnson (1952) in which the several surfactants studied were unable to significantly increase the growth of chicks fed a diet with which the antibiotic stimulus has been observed on numerous occasions. The inability of surfactants to stimulate the growth of baby pigs also agrees with unpublished work in the rat (Johnson, 1952) in which surfactants were shown unable to stimulate growth ("spare" B vitamins) on certain B vitamin low diets as several antibiotics are capable of doing.

The slow growth realized in experiment 2 was due partially, at least, to housing the animals in non-air-conditioned laboratories in which the temperature was observed on several occasions to be over 100 degrees F.

The statistical analysis of the paired data in the third experiment, using the t-test and regression equations of initial weight and feed consumption on final weight, revealed the effect of the antibiotic concentrate, Number 802, to be highly significant (P less than 0.01).

Summary

A study of several possible growth stimulants for baby pigs was made using 29 animals fed a purified diet. Of those compounds studied, sulfisoxazole (3,4-dimethyl-5-sulfanilamido-isoxazole) and surface acti-

vating agents either alone or in a mixture of 8, failed to stimulate the growth of baby pigs up to 5 weeks of age.

When fed at a level of 90 mg. per kg. dry matter diet, arsanilic acid (p-amino-phenylarsonic acid) significantly increased the growth and feed consumption of baby pigs up to 5 weeks of age.

The effect of the antibiotic concentrate, Number 802, on the final weight of baby pigs up to 8 weeks of age, was observed to be highly significant.

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AMINO ACID SUPPLEMENTATION OF A CORN-COTTONSEED MEAL DIET FOR GROWING-FATTENING SWINE [1, 2]

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IN the past the cotton plant has been grown primarily for its fiber; however, cottonseed meal which is obtained in the production of oil from cottonseed is one of our most important protein supplements. In volume produced, it ranks second only to soybean oil meal among the protein concentrates. Although its use for cattle has been unrestricted, the amount fed to swine and poultry has been limited by its content of a toxic substance shown by Georgeson *et al.* (1895) to be free gossypol. In recent years, certain processors through development of new processing methods have been successful in manufacturing a cottonseed meal which Stephenson *et al.* (1952) fed to swine as the sole protein supplement without toxic effects. With the toxic factor removed, there was another question to be answered, this concerning the quality of the cottonseed protein. The two feeding trials reported herein were conducted to determine the need for lysine, methionine, tryptophan, and fish solubles in a corn-cottonseed meal diet for growing-fattening pigs. They were also designed to study the optimum levels at which lysine and tryptophan could be added.

Experimental

Data from two separate feeding trials are reported herein. The crossbred pigs (Duroc X Poland China and Minnesota No. 1 X [Duroc X Poland China]) were weaned and wormed at forty-five days of age and distributed at random into the experimental lots. Two lots of five pigs received each treatment in the first experiment whereas in the second experiment there were five pigs in one replicate and four pigs in the other. Each lot of pigs was maintained in a pen equipped with

[1] Based on a portion of a thesis submitted to the Graduate School at the University of Arkansas, January, 1954, by the Senior Author in partial fulfillment of the requirements for the M.S. Degree.

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[3] We are indebted to Dow Chemical Company, Midland, Michigan, through courtesy of Dr. R. W. Colby, for the amino acids used in this study.

a concrete floor and a self-feeder and waterer. The floor and waterer were scrubbed and fresh oat straw bedding added daily.

Experimental diets and tap water were supplied *ad libitum* during each of the four week feeding trials. The composition of the basal diet is given in table 1. The levels at which the amino acids and fish solubles were added to the basal diet are shown in tables 2 and 4 respectively.

TABLE. 1. COMPOSITION OF BASAL DIET

Ingredient	Pounds
Ground yellow corn	67.7
Cottonseed meal [1]	25.0
Alfalfa meal	5.0
Dicalcium phosphate	1.0
Ground limestone	0.5
Salt (iodized)	0.5
Vitamins [2]	...
Terramycin (5 grams/lb.)	0.1

[1] Cottonseed meal was made by the pre-press solvent process and contained 0.018% free gossypol.

[2] The following vitamins were added to each 100 pounds of basal mixture: 272,000 I. U. Vitamin A, 68,000 I. C. U. Vitamin D_3, 200 mg. riboflavin, 200 mg. pantothenic acid, 200 mg. niacin, 9851 mg. choline, and 1 mg. Vitamin B_{12}.

Cottonseed Meal Used

Cottonseed meal produced by the pre-press solvent process was used in these experiments. This meal contained 43 percent protein, 0.73 percent total gossypol and 0.018 percent free gossypol. The percentage of nitrogen soluble in dilute alkali was determined according to the method of Lyman *et al.* (1953) and found to be 73 percent.

Statistical Methods Used

An analysis of variance for average daily weight gains was made and statistical significance was determined from the F value (Snedecor 1945). Any statement of significance herein is based on that analysis.

Results and Discussion

First Experiment

The average daily weight gains of pigs in the first experiment is shown in table 2 and a statistical analysis of these data is given in table 3. In this experiment the addition of 0.3 percent dl lysine [4] to the

[4] The lysine fed in both experiments was di lysine monohydrochloride.

TABLE 2. SUPPLEMENTARY VALUES OF FISH SOLUBLES AND CERTAIN AMINO ACIDS WHEN ADDED TO A CORN-COTTONSEED MEAL DIET FOR SWINE

Supplement to Basal Diet	Avg. Init. Weight, Lb.	Avg. Final Weight, Lb.	Daily Gain, Lb.		Feed per Lb. of Gain, Lb.
			Mean	S.E.	
None	34 [a]	49	0.55	.108	4.40
	38	53	0.52	.051	6.70
3% fish solubles	37	59	0.79	.100	3.35
	36	57	0.75	.067	4.95
0.3% dl lysine	34	57	0.81	.127	3.15
	37	62	0.90	.107	3.35
0.3% dl lysine and 3% fish solubles	36	64	1.00	.049	3.04
	37	64	0.94	.113	3.56
0.2% dl lysine and 3% fish solubles	37	72	1.24	.34	3.26
	39	76	1.35	.149	3.06
0.1% dl lysine and 3% fish solubles	36	80	1.55	.205	2.69
	39	78	1.41	.057	3.07
0.05% dl lysine and 3% fish solubles	36	57	0.72	.081	3.96
	38	68	1.07	.078	3.16
0.05% dl methionin, 0.3% dl lysine and 3% fish solubles	35	71	1.19	.141	3.10
	36	67	1.08	.075	3.29
0.01% dl tryptophan and 3% fish solubles	36	61	0.90	.138	3.27
	38	75	1.30	.087	3.27
0.01% dl tryptophan, 0.05% dl methionine, 0.3% dl lysine and 3% fish solubles	37	69	1.15	.143	3.35
	38	76	1.41	.040	3.09

[a] Each replicate pen contained five pigs.

TABLE 3. STATISTICAL ANALYSIS OF DATA PRESENTED IN TABLE 2

Source of Variation	Degrees of Freedom	Mean Square
Replication	1	.1283
Treatment	9	.7904 **
Between levels of dl lysine (fed in presence of fish solubles)	3	.7465 **
0.3 dl lysine vs no dl lysine	1	.4730 *
Fish solubles vs no fish solubles	1	.2761
dl methionine vs no dl methionine	1	.2122
dl trypophan vs no dl tryptophan	1	.5347 **
0.3% dl lysine vs fish solubles + 0.3% dl lysine	1	.0700
Error	89	.0647

* Difference between the means statistically significant (P less than .05).
** Difference between the means statistically highly significant (P less than .01).

basal diet resulted in a significant response in growth of pigs. This agrees with the work of Hamilton (1950) who reported that lysine was a limiting amino acid in cottonseed meal and with Stephenson *et al.* (1952) who obtained a response by adding 0.3 percent dl lysine to a corn-cottonseed meal diet for swine.

Although in the study reported herein a significant growth response was obtained by feeding 0.3 percent dl lysine, this was not the most effective level used as 0.1 percent supplementary dl lysine promoted a greater increase in growth than did the 0.3 percent, 0.2 percent or the 0.05 percent levels.

The addition of fish solubles to the swine diet resulted in a growth response which approached significance. This confirmed the data reported by Noland (1951) who found that fish solubles improved a corn-cottonseed meal diet for pigs. Although a growth response was obtained, it was impossible to determine from the data presented in table 2 whether the response was due to an unidentified factor or to the small amounts of amino acids present in the fish solubles.

The addition of dl tryptophan to the diet at the 0.01 percent level resulted in a swine growth response which was statistically highly significant. The response obtained by adding 0.05 percent dl methionine, however, was not significant.

In this experiment, significant increases in growth rate were paralleled by an increase in efficiency of feed utilization.

Second Experiment

As indicated in table 4, the basal diet used in this experiment was the same as that used in the first experiment except that it also contained 0.1 percent additional dl lysine.

The statistical analysis of data obtained in this study indicates that the addition of dl tryptophan to the pig diet at the levels shown in table 5 resulted in a significant growth response when fed in the presence of fish solubles but not when fed in the absence of fish solubles. The addition of fish solubles alone did not alter the growth rate significantly and from these data it was again impossible to determine whether the response obtained by adding dl tryptophan only in the presence of fish solubles was due partially to unidentified factors or to a more optimum amino acid balance.

The response obtained by feeding 0.05 percent dl methionine was not significant. Likewise, there were no significant differences between the

TABLE 4. THE SUPPLEMENTARY VALUE OF DL TRYPTOPHAN FOR GROWING-FATTENING PIGS FED A RATION COMPOSED PRIMARILY OF CORN AND COTTONSEED MEAL

Supplement to Basal Diet [a]	Avg. Init. Weight, Lb.	Avg. Final Weight, Lb.	Daily Gain, Lb.		Feed per Lb. of Gain, Lb.
			Mean	S.E.	
None	43 [b]	80	1.32	.069	3.40
	50	84	1.22	.141	3.34
3% fish solubles	40	74	1.22	.111	3.18
	50	80	1.42	.111	3.54
.005% dl tryptophan	40	71	1.11	.059	3.02
	50	85	1.25	.140	3.42
.01% dl tryptophan	43	83	1.42	.076	3.46
	50	83	1.18	.090	3.30
.02% dl tryptophan	44	81	1.32	.102	3.95
	51	85	1.22	.119	3.18
3% fish solubles and .005% dl tryptophan	44	82	1.36	.074	3.59
	49	87	1.36	.098	2.95
3% fish solubles and .01% dl tryptophan	45	87	1.46	.082	3.34
	50	90	1.42	.067	3.96
3% fish solubles and .02% dl tryptophan	44	82	1.36	.130	3.34
	50	87	1.32	.090	2.86
.05% dl methionine	42	82	1.42	.106	3.84
	50	89	1.40	.075	2.88
.05% dl methionine, .005% dl tryptophan and 3% fish solubles	45	85	1.42	.073	3.09
	49	86	1.32	.076	3.83

[a] Identical to basal diet used in the first experiment except that the basal diet used in the second experiment contained 0.1% dl lysine.

[b] The top listed replicate in each treatment contained 5 pigs whereas the other contained 4 pigs.

TABLE 5. STATISTICAL ANALYSIS OF DATA PRESENTED IN TABLE 4

Source of Variation	Degrees of Freedom	Mean Square
Replication	1	.1882 *
Treatment	9	.0768 *
dl tryptophan vs no dl tryptophan (fed in presence of fish solubles)	1	.2043 *
dl methionine vs no dl methionine	1	.0813
fish solubles vs no fish solubles	1	.0014
between levels of dl tryptophan (fed in absence of fish solubles)	2	.0469
between levels of dl tryptophan (fed in presence of fish solubles)	2	.0441
dl tryptophan vs no dl tryptophan (fed in absence of fish solubles)	1	.0943
Error	78	.0380

* Difference between the means statistically significant (P less than .05).

growth response obtained by feeding different levels of dl tryptophan either in the presence or absence of fish solubles.

In this experiment as in the first experiment, a significant increase in growth rate was accompanied by an increase in efficiency of feed utilization.

Summary

A significant growth response was obtained by supplementing a corn-cottonseed meal type diet for swine with dl lysine. There was a highly significant difference in the response resulting from feeding different levels of dl lysine. The optimum level of supplementary dl lysine fed in the presence of fish solubles was 0.1 percent. Levels of supplementary dl lysine greater than 0.1 percent appeared to depress growth, whereas, levels lower than 0.1 percent failed to support maximum growth.

The addition of dl tryptophan at levels used in these experiments promoted growth significantly when added in the presence of fish solubles.

The addition of 0.05 percent dl methionine did not result in a statistically significant growth response.

Significant increases in growth rate were paralleled by increases in efficiency of feed utilization.

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GROWTH AND CARCASS CHARACTERISTICS OF PIGS FED ANTIBIOTICS FOR PART OR ALL OF THE GROWING-FATTENING PERIOD [1]

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THREE reports in the early months of 1950 (Jukes *et al.*, 1950; Luecke *et al.*, 1950; and Carpenter, 1950) afforded evidence of the effectiveness of specific antibiotics in swine feeding. These reports have been followed by numerous other ones and today antibiotics are considered standard ingredients in rations for growing pigs.

The study reported herein was started in 1951 to obtain comparative data on aureomycin, terramycin and procaine penicillin. Observations made earlier had indicated that young pigs were more likely to benefit from the feeding of antibiotics than older ones. Therefore, provision was made to study the effect of antibiotic withdrawal from the ration when the pigs reached a weight of approximately 125 pounds. Most of the studies of vitamin B_{12} and antibiotics at other Stations have been made with corn-soybean oil meal type of diets. At this Station, the ration commonly fed to weanling pigs contains some dry-rendered tankage. Thus, it was considered essential to determine whether vitamin B_{12} fortification of this mixed ration was necessary. A preliminary report of these experiments was made earlier (Hanson *et al.*, 1952).

Experimental Procedure

Two experiments were conducted. In the first one (1951) eight lots of nine pigs each were fed. The pigs were farrowed on concrete and kept there until weaning at approximately 8 weeks of age. They were started on the experiment the day they were weaned. In the second experiment, the following year, eight lots of 10 pigs each were fed. About one-third of the pigs used were weaned at 8 weeks and held in dry lot for about 2 weeks more before the experiment started. The remainder were 7-week-old pigs that were alloted to the test pens the day after

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they were weaned. All of the pigs had been on concrete from birth. Most of the pigs in each experiment had been used to study the value of various antibiotics added to a creep ration during the suckling period. In 1951 their dams were fed a standard mixed ration during lactation, without added vitamin B_{12} or an antibiotic. In 1952 the dams' rations had 10 mg. of vitamin B_{12} added per ton of feed. The pigs were sorted on the basis of litter, sex and initial weight into eight groups. The groups were assigned randomly to one of the following treatments:

Lot No.	Treatment
1	Basal mixture only
2	Basal+vitamin B_{12}
3	Basal+vitamin B_{12}+aureomycin to 125 lbs.
4	Basal+vitamin B_{12}+aureomycin to 200 lbs.
5	Basal+vitamin B_{12}+terramycin to 125 lbs.
6	Basal+vitamin B_{12}+terramycin to 200 lbs.
7	Basal+vitamin B_{12}+procaine penicillin to 125 lbs.
8	Basal+vitamin B_{12}+procaine penicillin to 200 lbs.

The pigs were housed in a barn with outside paved runways. They were provided with automatic water supplies and were self-fed the feed mixtures given in table 1.

Three pigs were slaughtered from each lot in 1951. All of the pigs that reached market weight in the 1952 experiment were slaughtered

TABLE 1. BASAL MIXTURES FED

Weight Range of Pigs	From Weaning to 125 Lb.	From 125 Lb. to Slaughter
Ingredients	Percent	Percent
Corn, ground (yellow No. 2)	66.6	77.8
Soybean oil meal[1]	15.3	10.2
Tankage (dry rendered—60%)	6.7	4.5
Linseed oil meal[1]	3.3	2.2
Alfalfa meal[2]	6.7	4.5
Steamed bone meal	0.7	0.4
Salt, iodized	0.7	0.4
Estimated protein	18	15

[1] Expeller process meals fed in 1951; solvent process meals fed in 1952.

[2] Excellent quality, field-cured meal fed in 1951; dehydrated, 17% protein meal fed in 1952.

Antibiotic and vitamin B_{12} supplements:

Vitamin B_{12} was added to all lots except 1, 3 and 4 in the form of a feed supplement (Merck) in 1951 and as crystalline B_{12} in mannitol (Merck) in 1952. Aurofac (Lederle) was fed to lots 3 and 4 to supply vitamin B_{12} and aureomycin. After the pigs in lot 3 reached 125 pounds, the respective Merck products were added as a source of B_{12}. Bi-Con TM-5 (Pfizer) was the source of terramycin fed to lots 5 and 6. Crystalline procaine penicillin (Merck) was fed to lots 7 and 8 in 1951, and Merck's antibiotic feed supplement was fed in 1952.

Vitamin B_{12} was fed at a level of 10 mg. per ton and the respective antibiotics were fed at a level of 10 grams per ton, in all cases.

for carcass evaluation. In order to obtain comparable data, the individual pigs were removed from the test lots as soon as they reached slaughter weights of 200–225 pounds. The first 10 head were slaughtered in the University Meat Shop and the remainder were trucked about 100 miles to the Geo. A. Hormel and Co. plant, Austin, Minnesota for slaughter and processing. In the latter case, weekly shipments were made. The extreme live-weight range was 190–225 pounds, most of the pigs being in the range of 210–220 pounds (3 pigs less than 200 lb.). Slaughtering was done over a period of about 8 weeks. Thus, as the animals were slaughtered one-half of each carcass was processed into wholesale cuts and frozen. The other half was boned and ground, and samples were taken for chemical analyses. When slaughter was completed the previously frozen hams, bellies and picnics were put through the regular curing and smoking procedures at the same time.

Results and Discussion

A summary of the feed-lot data for the various periods of each experiment and also the means of the two experiments are given in table 2.

TABLE 2. VITAMIN B_{12}, AUREOMYCIN, TERRAMYCIN AND PROCAINE PENICILLIN AS SUPPLEMENTS TO A MIXED RATION FOR GROWING-FATTENING PIGS FED IN DRY LOT. (9 PIGS PER LOT IN EXPERIMENT 1; 10 PIGS PER LOT IN EXPERIMENT 2. ALL WEIGHTS IN POUNDS

Lot No.	1	2	3	4	5	6	7	8
Ration Supplement [1]	None Control	B_{12}	B_{12}+A to 125 lb.	B_{12}+A to 200 lb.	B_{12}+T to 125 lb.	B_{12}+T to 200 lb.	B_{12}+P to 125 lb.	B_{12}+P to 200 lb.
		From start [2] to 125 lb. average weight						
No. pigs finished [3]	18	18	19	19	19	19	18	19
Av. daily gain								
Exp. 1	1.05	1.17	1.37	1.45	1.31	1.39	1.32	1.35
Exp. 2	1.13	1.23	1.45	1.43	1.34	1.34	1.32	1.37
Mean	1.09	1.20	1.41** [4] **	1.44** **	1.33** *	1.37** **	1.32** *	1.36** **
Av. daily feed								
Exp. 1	3.4	3.6	4.3	4.4	4.0	4.0	3.9	3.9
Exp. 2	3.8	4.1	4.7	4.7	4.4	4.6	4.4	4.5
Mean	3.6	3.9	4.5	4.6	4.2	4.3	4.1	4.2
Feed per/100 lbs. gain								
Exp. 1	327	310	315	304	302	291	296	285
Exp. 2	334	338	323	333	330	340	335	328
Mean	331	324	319	319	316	315	315	307

TABLE 2. (continued)

Lot No.	1	2	3	4	5	6	7	8
Ration Supplement [1]	None Control	B_{12}	B_{12}+A to 125 lb.	B_{12}+A to 200 lb.	B_{12}+T to 125 lb.	B_{12}+T to 200 lb.	B_{12}+P to 125 lb.	B_{12}+P to 200 lb.
			From 125 lb. to approximately 200 lb.					
No. pigs finished [3]	18	17	19	19	19	18	18	19
Av. daily gain								
Exp. 1	1.52	1.89	1.75	1.92	1.68	1.97	1.65	1.84
Exp. 2	1.51	1.88	1.84	1.91	1.76	1.88	1.78	1.77
Mean	1.52	1.88**	1.80**	1.91**	1.72**	1.91**	1.71*	1.80**
Av. daily feed								
Exp. 1	5.9	7.1	6.7	7.8	6.8	7.5	6.3	7.2
Exp. 2	6.3	8.2	8.0	7.8	7.6	7.4	7.7	7.4
Mean	6.1	7.7	7.4	7.8	7.2	7.5	7.0	7.3
Feed per/100 lb. gain								
Exp. 1	386	379	391	406	407	383	382	388
Exp. 2	415	434	433	407	433	396	435	415
Mean	402	407	415	407	422	391	410	403
			Entire Feeding Period					
No. pigs finished [3]	18	17	19	19	19	18	18	19
Av. daily gain								
Exp. 1	1.21	1.40	1.53	1.63	1.46	1.57	1.45	1.54
Exp. 2	1.26	1.45	1.61	1.63	1.53	1.58	1.50	1.55
Mean	1.24	1.43**	1.57** *	1.63** **	1.49**	1.57** *	1.48**	1.54** *
Av. daily feed								
Exp. 1	4.3	4.8	5.3	5.7	5.1	5.1	4.9	5.1
Exp. 2	4.6	5.5	6.1	6.0	5.9	5.8	5.8	5.7
Mean	4.5	5.2	5.7	5.9	5.5	5.5	5.3	5.5
Feed per/100 lb. gain								
Exp. 1	352	340	350	349	350	326	335	332
Exp. 2	368	381	376	369	383	369	383	371
Mean	360	361	365	360	368	350	360	353

[1] A=aureomycin; T=terramycin; P=procaine penicillin. Each antibiotic was fed at the rate of 10 grams per ton of feed. Vitamin B_{12} fed at the rate of 10 mg. per ton of feed.

[2] Initial weight was 33 lb. in Exp. 1 and 36 lb. in Exp. 2.

[3] Exp. 1: One pig died in lot 1 and one pig died in lot 6 from acute erysipelas.
Exp. 2: One pig was removed from lot 2 because it was subnormal and another was removed because of a badly injured leg and subsequent lameness. One pig was removed from lot 7 due to a general dermatitis and unthriftiness.

[4] *=significance at 5%, **=significance at 1%. The upper asterisks relate to comparisons with lot 1; the lower asterisks relate to lot 2.

The data for the two experiments were combined for covariance analysis of initial body weights (weaning and about 125 lb. wt.) and daily gains (Snedecor, 1946). The summary of the analyses made for various periods is given in tables 3 and 4.

TABLE 3. COVARIANCE ANALYSIS OF INITIAL BODY WEIGHTS (x) AND AVERAGE DAILY GAINS (y)

Source of Variation	Degree of Freedom	Sum of Squares and Products			Errors of Estimate		
		x^2	xy	y^2	Sum of Squares	Degree of Freedom	Mean Square
From Start to About 125 lb. Average Live Weight							
Total	148	12783.8	154.2870	7.3946			
Rations	7	21.7	1.5489	1.3809			
Trials	1	553.0	4.8164	0.0421			
Ration X Trials	7	24.5	0.0682	0.3103			
Error	133	12184.6	147.8535	5.6613			
Pooled Error	140	12208.1	147.9217	5.9716	4.1793	139	0.030067
For testing significance of adjusted rations means					1.3464	7	0.1923**
For testing significance of adjusted trials means					0.0063	1	0.0063
From 125 lb. to About 200 lb. Average Live Weight							
Total	146	58666.0	150.286	10.1009			
Rations	7	506.9	13.042	2.2891			
Trial	1	8.8	0.899	0.0915			
Ration X Trial	7	594.9	18.043	0.7640			
Error	131	57555.4	118.302	6.9563			
Pooled Error	138	58150.3	136.345	7.7203	7.4006	137	0.05402
For testing significance of adjusted rations means					2.2283	7	0.3183**
For testing significance of adjusted trials means					0.0873	1	0.0873

** Highly significant (P less than .01).

Least Significant Differences at 5% and 1%

From start to 125 pounds			From 125 to 200 pounds		
N	18	19	N	18	19
17	0.119 0.160	0.118 0.158	17	0.160 0.215	0.1577 0.2118
18	0.117 0.158	0.116 0.155	18	0.1573 0.2113	0.1552 0.2082
19		0.114 0.153	19		0.1529 0.2051

Early Growth (from the Start to 125 lb.)

It is clear that the basal ration was deficient in vitamin B_{12}, even though it contained 6.7 percent dry-rendered tankage. The addition of this vitamin increased feed consumption and the rate of gain in both experiments. The increased gains were just slightly below the significance level at the 5 percent point (L.S.D. = 0.117). The addition of any one of the three antibiotics and B_{12} to the basal ration produced a highly significant increase in rate of gain. Each of the antibiotics produced a response which was significant (lots 3, 4, 6 and 8, P less than .01) (lots 5 and 7, P less than .05) over that of B_{12} alone

(lot 2). The differences between the antibiotics were not significant at the 5 percent level.

In Experiment 1 there appeared to be a slight increase in feed efficiency due to the feeding of vitamin B_{12} and the antibiotics. No consistent differences appeared in Experiment 2. The latter may be due to the fact that all creep rations were fortified with B_{12} during the

TABLE 4. COVARIANCE ANALYSIS OF WEANING WEIGHT (x) AND DAILY GAINS FROM WEANING TO 200 POUNDS WEIGHT (y)

Source of Variation	Degree of Freedom	Sum of Squares and Products			Errors of Estimate		
		x^2	xy	y^2	Sum of Squares	Degree of Freedom	Mean Square
Total	146	12691.4	86.4365	5.4811			
Rations	7	37.6	2.6765	1.5187			
Trial	1	558.1	10.0985	0.1827			
Ration X Trial	7	56.9	1.1827	0.2924			
Error	131	12038.8	72.4788	3.4873			
Pooled Error	138	12095.7	73.6615	3.7797	3.3311	137	0.0243
For testing significance of adjusted rations means					1.4870	7	0.2124**
For testing significance of adjusted trials means					0.0769	1	0.0769

** Highly significant (P less than .01).

Least Significant Differences at 5% and 1%

From weaning to 200 lbs.

N	18	19
17	0.107 0.144	0.1057 0.1421
18	0.1056 0.1419	0.1041 0.1396
19		0.1026 0.1376

suckling period in 1952 and the average quality and thrift of the pigs was slightly greater than that of the 1951 pigs.

There was a low incidence of scours in the test pigs early in the experimental period (Exp. 1) but it did not persist for more than a few days. There was scouring in the control lot (Exp. 1) for about 3 weeks at the start of the experiment. A few pigs in this lot were treated individually with sulfaguanidine, orally. In Experiment 2, there were two pigs in each of lots 1 and 2 that scoured for a few days. These animals were given sulfaguanidine, orally, and the scouring stopped. There was no scouring in any of the other lots.

Late Growth and Fattening (from 125 to "200" lb.)

That the basal mixture is deficient in vitamin B_{12}, even for older heavier pigs, is clearly shown by comparing lots 1 and 2. The differences between the lots are nearly identical in both experiments and are highly significant. During this feeding period the feed mixtures contained 4.5 percent dry-rendered tankage. Further evidence of the need for vitamin B_{12} is supplied by lots 3, 5 and 7 which were fed the same feed mixture as lot 2 during this part of the experiment.

The withdrawal of the respective antibiotics from lots 3, 5 and 7 in Experiment 1 had a pronounced depressing effect on feed consumption and rate of gain (compare with lot 2). Wilson (1952) observed a similar depressing effect on rate of gain, but not of feed consumption, from the withdrawal of terramycin from the ration when the pigs weighed about 135 pounds, in a single experiment also conducted in 1951.

In Experiment 2 there was no adverse effect on feed consumption from the withdrawal of the antibiotics. The continued feeding of aureomycin or terramycin appeared to be worthwhile in terms of rate of gain. Penicillin had no effect on the rate of gain. The small differences in feed efficiency between the lots fed an antibiotic and those from which the antibiotic had been withdrawn were in favor of the former in each comparison. However, the feeding of any of the three antibiotics during this period did not produce a significant increase in rate of gain.

In considering the mean rate of gain of the two experiments it will be noted that the pigs which were not fed an antibiotic in the early part of the experiment (lot 2) gained significantly faster (P less than .05) during this period than the pigs which were fed terramycin (lot 5) or procaine penicillin (lot 7) up to a weight of 125 pounds only. The pigs fed aureomycin up to the 125-pound weight only also gained less than the lot 2 pigs, but the difference was not significant. The adverse effect of antibiotic withdrawal on gain was greatest for terramycin.

Entire Feeding Period (from Start to Approximately 200 lb.)

For the entire feeding period, the addition of vitamin B_{12} to the basal ration produced a highly significant (P less than .01) increase in rate of gain, even though the supplement fed contained 20 percent of high quality, dry-rendered tankage. The addition of aureomycin produced a further increase that was highly significant. The addition of terramycin or procaine penicillin increased gains significantly (P less than .05). The feeding of aureomycin up to a weight of 125 pounds increased

the average rate of gain for the entire feeding period significantly. Pigs fed terramycin or procaine penicillin to a weight of 125 pounds averaged slightly faster gains, but the differences were not significant.

The feeding of added vitamin B_{12} or of any of the antibiotics did not affect the feed efficiency of the pigs significantly. The most important contribution of the antibiotics in these experiments was to reduce the time required to get the pigs to market weight, and the increase in uniformity of the pigs fed the drugs.

It would appear from these data that when environmental conditions are such that an antibiotic will have a significant effect on the growth rate of the newly weaned pig, the antibiotic should be fed from weaning to market weight. Wallace *et al.* (1953) have reached similar conclusions from a study of aureomycin withdrawal. Burnside *et al.* (1953) compared intermittent feeding of aureomycin with continuous feeding and concluded that continuous feeding was preferable.

Carcass Evaluation

Since only a few hogs from Experiment 1 could be slaughtered and the slaughter weights were highly variable, the data obtained are omitted from this report. A summary of the carcass data obtained in Experiment 2 is given in table 5. The most rapidly gaining pigs were slaughtered at the Station in order to obtain relatively uniform slaughter weights. These included 10 head and came from all lots but lot 8. One pig from the latter lot reached slaughter weight at the same time but was retained for the breeding herd.

The same procedures were followed in obtaining carcass measurements on the first 10 pigs slaughtered as were followed on the 66 head slaughtered at the Geo. A. Hormel and Co. plant. Thus all of the physical measurements are included in table 5. The chemical analyses include only those pigs slaughtered at the packing plant. In order to obtain representative samples for analysis, one-half of each carcass was skinned, boned and thoroughly ground. Several samples were taken from each ground carcass, pooled and sub-sampled for the analyses. Moisture, crude protein and ash were determined according to official A.O.A.C. procedures by personnel of the quality control laboratory of Geo. A. Hormell and Co. Fat content of carcasses was determined by difference.

The raw averages indicate that the control pigs had less backfat than any of the other lots; the chemical analyses indicate that they had a higher protein and moisture content and less total carcass fat than any

of the other lots. The control pigs averaged 20 days older at slaughter than any other lot, and thus they fattened less rapidly than the others. The pigs in lot 4 had a slightly greater average backfat than any other lot, but the pigs in lot 2, 6 and 7 had the highest total carcass fat content.

TABLE 5. CARCASS DATA FROM HOGS FED ANTIBIOTICS FOR PART OR ALL OF THE FEEDING PERIOD. A SUMMARY OF EXPERIMENT 2. LOT AVERAGES

Lot No.	1	2	3	4	5	6	7	8
Treatment[1]	Control	B_{12}	B_{12}+A to 125 lb.	B_{12}+A to 200 lb.	B_{12}+T to 125 lb.	B_{12}+T to 200 lb.	B_{12}+P to 125 lb.	B_{12}+P to 200 lb.
No of pigs	10	8	10	10	10	10	9	9
Daily gain per pig[2]	1.26	1.45	1.61	1.63	1.53	1.58	1.50	1.55
Final feed lot wt.	209	216	214	213	213	213	211	211
Shrunk live wt.	198	206	202	201	201	201	200	200
Chilled carcass wt.	142	150	146	149	147	148	145	145
Dressing percent	71.7	72.8	72.3	74.1	73.1	73.6	72.5	72.5
Length of carcass, cm.	72.6	71.6	71.2	71.7	70.2	69.9	71.1	70.8
Backfat thickness,[3] cm.	4.05	4.59	4.56	5.24	4.49	4.85	4.66	4.42
Carcass yield,[4] %	62.0	60.6	59.3	60.2	59.6	58.2	59.4	60.8
Cutting fat, %	25.2	26.8	27.0	26.8	26.1	28.5	26.8	24.8
			Chemical Analyses					
No. of pigs[5]	9	6	9	7	9	9	8	9
Moisture,%	37.3	33.4	35.2	35.2	35.0	33.7	33.9	36.4
Ash, %	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.6
Protein (NX6.25), %	10.1	9.2	9.5	9.6	9.6	9.3	9.2	9.8
Fat,[6] %	52.0	56.8	54.8	54.7	54.9	56.5	56.4	53.2

[1] A=aureomycin; T=terramycin; P=procaine penicillin.
[2] All weights in pounds.
[3] An average of measurements at first rib, last rib and last lumbar.
[4] Yield of 5 primal cuts—ham, loin, belly, boston butt, picnic.
[5] The pigs slaughtered at University Farm are not included in the chemical analyses.
[6] Obtained by difference.

Carcass weights were most variable in the control lot, varying from 121 to 153 pounds and least variable in lot 2 (146–152 pounds). Therefore, covariance analyses (Snedecor, 1946) were made of carcass weight and moisture, ash, protein, and fat. These analyses revealed no significant differences due to ration treatments for moisture, protein or fat. There was a significant effect of rations on ash content. The figures for ash in table 5 were rounded to the nearest number beyond the decimal for clarity. The actual means were 0.644, 0.550, 0.500, 0.529, 0.511, 0.489, 0.469 and 0.561 for lots 1 through 8, respectively. Thus, the carcasses in lot 3, 5, 6 (L.S.D. = 0.1105) contain significantly

less ash (P less than .05) than the control carcasses, and the difference is highly significant (P less than .01) for the carcasses in lot 7 (L.S.D. = 0.1583). The reasons for these differences are not apparent, especially since they did not appear in lot 8. It is interesting to note that from the carcass analyses published by Perry *et al.* (1953) it may be deduced that carcasses of pigs fed aureomycin contained only 0.3 percent ash, whereas the carcasses of control pigs contained 0.6 percent ash.

One-half of each carcass was processed into wholesale cuts at time of slaughter. These were frozen and held in storage until the last animals had been slaughtered. All of the cuts were then cured and smoked at the same time. The cured and smoked cuts were inspected by a panel of meat experts and other interested persons. There were no differences between the various lots which could be attributed to rations, though the control lot carcasses appeared slightly less fat.

There is a lack of agreement in the literature as to the effect of antibiotics on carcass quality. Bowland *et al.* (1951) reported a reduction in carcass quality (reduction in carcass length and increased backfat) from feeding aureomycin and suggested that this "may be due to very fast gains during the finishing period". Catron *et al.* (1952) reported no significant effect on carcass quality from feeding aureomycin. Differences in rate of gain in that experiment were not large. Perry *et al.* (1953) report a highly significant increase in carcass fat and a highly significant decrease in carcass moisture and protein of pigs fed aureomycin. Here, there was a highly significant increase in rate of gain of the aureomycin-fed pigs. Wallace *et al.* (1954) found thicker average backfat in pigs fed aureomycin and a low- or high-protein ration, but not in pigs fed aureomycin and an intermediate level of protein. In the latter case there was no difference in rate of gain of the two lots. The differences in back fat measurements were not significant at the 5 percent level. Pierce (1954) has reported no significant carcass effects due to the feeding of aureomycin or terramycin. In that experiment the differences in rate of gain were 0.28 pound daily greater for the aureomycin-B_{12} supplemented group and 0.23 pound daily greater for the terramycin fed pigs (see Wilson, 1952). However, during the period from 125 to 225 pounds the control pigs made very rapid gains. Huang and McCay (1953) have reported an increase in fat content of carcasses from swine fed terramycin. In their experiment terramycin produced a highly significant (P less than .01) increase in rate of gain.

Wilson *et al.* (1953) have reported data that suggest opposite effects from that reported by other Stations. In their experiments three levels of protein were fed. Their data show a significant *decrease* in percent of lean cuts when a high-protein ration was supplemented with vitamin B_{12} and aureomycin. On the other hand, the data show an *increase* in percent of lean cuts when intermediate- or low-protein rations were fed with aureomycin and B_{12} supplements. Their data for backfat measurements show no significant differences.

McMeekan (1940) demonstrated clearly that level of feed intake, especially during the fattening period, has a marked influence on carcass fatness. Recently Crampton *et al.* (1954) demonstrated that restriction of feed intake during the finishing period reduced fat deposition and increased the percentage of lean in swine carcasses. In most of the research in which increased fat deposition has been reported due to the feeding of an antibotic, there has been increased feed consumption and increased rate of gain associated with the fatter carcasses.

In the experiment reported herein, it should be noted that while there was a trend toward fatter carcasses when the pigs were fed antibotic and B_{12} supplements, the pigs fed B_{12} but no antibiotic (lot 2) were just as fat as the former. The B_{12} lot made very rapid gains during the period from 125 to 200 pounds, the fattening period. In this experiment the trend toward fatter carcasses was associated with rate of gain.

It is concluded that the antibiotics *per se* (fed in this experiment) do not affect carcass quality. This conclusion is supported by additional unpublished data obtained at this Station with 33 littermate pairs of pigs (Wingert *et al.* 1953). In the latter experiment there was a mean difference of only 7 days in the time required to reach slaughter weight.

Summary

One hundred and fifty-two weanling pigs were fed in two experiments to compare the value of aureomycin, terramycin and procaine penicillin when fed for part or all of the feeding period, and to determine the need for vitamin B_{12} supplementation of a ration which contained dry-rendered tankage.

The addition of vitamin B_{12} to the basal ration produced a highly significant (P less than .01) increase in rate of gain, even though the supplement fed contained 20 percent of high quality, dry-rendered tankage. The addition of aureomycin produced a further increase that was highly significant. The addition of terramycin or procaine penicillin increased gains significantly (P less than .05)

The withdrawal of the antibiotics when the pigs weighed an average (lot weight) of 125 pounds had a pronounced depressing effect on daily feed consumption and rate of gain in the first experiment. In the second experiment there was no adverse effect on feed consumption, but withdrawal of aureomycin or terramycin had a slight depressing effect on rate of gain.

The feeding of added vitamin B_{12} or of any of the antibiotics did not affect feed efficiency of the pigs significantly. The percent of moisture, crude protein or fat in the carcasses was not affected significantly by the feeding of any of the antibiotics or of vitamin B_{12}. The percent of ash in the carcasses was decreased significantly in all but one of the lots of pigs fed antibiotics.

It is concluded that when environmental conditions are such that an antibiotic will have a significant effect on the growth rate of the newly weaned pig, the antibiotic should be fed from weaning to market weight, if maximum gains are desired. It is concluded also that aureomycin, terramycin or procaine penicillin *per se* do not directly affect carcass quality.

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THE VALUE OF UREA IN A LOW PROTEIN RATION FOR WEANLING PIGS [1]

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IT has been estimated that 50,000 tons of non-protein nitrogen feed supplements were available for feeding during the 1953–54 feeding season (Feed Survey Committee, 1953). The development of the non-protein nitrogen feed supplement industry is based on several hundred pieces of research, most of which pertain to ruminants. Reid (1953) has reviewed the studies dealing with urea as a protein supplement for ruminants.

Among the papers reporting studies with non-ruminants, there is a difference of opinion as to the ability of pigs to utilize urea. Grafe and Turban (1913) and Grafe (1913) reported that urea added to a ration for pigs increased nitrogen retention. Abderhalden and Lampe (1913) repeated Grafe's experiments but did not confirm his conclusions. Piepenbrock (1927) fed urea to 45 kg. gilts at levels of 20 to 45 gm. per head daily in alternate 2 week periods over a period of several weeks. He concluded that 30–40 percent of the dietary protein can be replaced by urea without decrease in weight gains of pigs. Braude and Foot (1942) concluded that urea is "without effect" as a source of protein for pigs.

Occasionally stale cattle feeds are fed to swine. In view of the increased use of urea in ruminant rations, and the dearth of data pertaining to swine, it seemed desirable to obtain further information on the effects of feeding urea to weanling pigs. The objectives of the present study were to determine the effect on acceptability to weanling pigs of a mixed dry ration containing urea; to measure, by growth rate and feed efficiency data, the protein-sparing effect of adding urea to a low (suboptimum) protein ration; and to observe any clinical evidence of toxicity.

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[2] Urea feed supplement was donated by E. I. duPont de Nemours and Company through the courtesy of Sidney F. Taylor. Antibiotic and vitamin supplements were donated by Lederle Laboratories, through the courtesy of Dr. R. F. Elliot. Acknowledgment is due Dr. M. O. Schultze, Department of Agricultural Biochemistry, for the crude protein analyses and for suggestions regarding the manuscript. Glen Swartz and associates fed and cared for the pigs.

Experimental Procedure

The experiment consisted of four replicates of each of three ration treatments. Two trials were conducted with spring farrowed pigs during the summer of 1953 and two trials were conducted with fall farrowed pigs during the winter of 1953–54. The pigs, with one exception (replicate 2 started one week after weaning) were started on test the day they were weaned, at approximately 8 weeks of age. The pigs were purebreds from the Station herd. Replicate 1 included 4 Chester Whites and 2 Poland Chinas per lot; Replicate 2 included 6 Chester Whites and Replicate 3 included 5 Durocs per lot. Replicate 4 was composed of 4 Poland Chinas and 2 Chester Whites per lot. The pigs were allotted to the treatment groups on the basis of litter, sex and weight.

All pigs were self-fed and self-watered and were housed in a barn provided with outside paved runways. Thus, the pigs in replicates 1 and 2 were continuously on concrete from birth to the conclusion of the experiment. The pigs in replicates 3 and 4 were farrowed in the barn but were with their dams on brome-grass pasture for a period of about 7 weeks during the suckling period. All of the pigs were creep fed a 16 percent protein starter during the suckling period.

The treatments employed included a low protein mixed ration which served as a negative control (Ration 1); a higher protein mixed ration as a positive control (Ration 3); and the low protein ration plus urea (Ration 2) to simulate the crude protein content of the positive control ration. Urea was added at the expense of corn in the form of duPont's "262".

The feed mixtures are given in table 1.

The protein level of each mixture was reduced when the pigs in a lot reached an average weight of approximately 125 lb. The urea level was reduced from the starting 1.5 percent to 1.0 percent of the base mixture when the pigs averaged 125 lb. in order to keep the crude protein content of the mixture more nearly like that of the positive controls.

Results and Discussion

The results are summarized in table 2, for each replicate in the experiment. These data show that the low protein ration (10.6%) was suboptimum for maximum growth of weanling pigs. The normal protein ration (14.5%) produced significantly greater live weight gains. The addition of 1.5 percent urea to the low protein ration did not increase the rate of gain but did increase slightly the feed requirement per lb. of gain.

During the later growth and fattening period, from 125 to 200 lbs. average weight, the pigs fed the low protein ration (10.0%) gained nearly as well as those fed the 10.6 percent protein ration. The addition of 1.0 percent urea to the low protein ration did not affect the rate of gain. There were two pigs in the latter lot that gained at a very subnormal rate, and they are omitted from the data in table 1. They ap-

TABLE 1. COMPOSITION OF FEED MIXTURES
(all weights in pounds)

Weight Range of Pigs	From Start to 125 lb. Average Weight			From 125 lb. to 200 lb. Average Weight		
Ration	1	2	3	1	2	3
Estimated crude protein, %	10.5	14.0	14.0	9.5	12.0	11.0
Av. crude protein by analysis, %[1]	10.6	13.6	14.5	10.0	11.7	10.6
Ingredients						
Ground yellow corn (no. 2)	88.5	87.0	80.2	90.8	89.8	88.5
Soybean oil meal (44%)	2.8	2.8	8.2	1.4	1.4	2.8
Tankage (dry rendered 60%)	1.2	1.2	3.6	0.6	0.6	1.2
Linseed oil meal (36%)	0.6	0.6	1.8	0.3	0.3	0.6
Alfalfa meal (dehydrated–17%)	5.0	5.0	5.0	5.0	5.0	5.0
Steamed bone meal (special)	1.4	1.4	0.7	1.4	1.4	1.4
Salt (trace mineralized) [2]	0.5	0.5	0.5	0.5	0.5	0.5
Urea (du Pont "262")	—	1.5	—	—	1.0	—
Antibiotic and vitamins[3]	+	+	+	+	+	+

[1] Corrected to 14% moisture.

[2] Guaranteed by the manufacturer to contain: Mn, 0.250%; Fe, 0.160%; Cu, 0.033%; Co, 0.010%; I_2 0.007%; Zn, 0.005%.

[3] Antibiotic and vitamin B_{12} feed supplement added at a rate calculated to supply 10 mg. vitamin B_{12} and 10 gm. aureomycin per ton. Vitamin B complex supplement added at a rate calculated to supply 1.0 mg. riboflavin, 2.0 mg. pantothenic acid, 4.5 mg. niacin, 5.0 mg. choline and 30 micrograms folic acid per lb. of feed.

peared to be in good health and thrift throughout the feeding period. One of these pigs gained 37 lb. and the other gained only 31 lb. during the last 44 days of this trial. Their litter mates in the low protein lot gained 85 and 86 lb., respectively, during the same period.

The addition of urea to the low protein ration did not affect the acceptability of the ration to the pigs. The urea-fed pigs ate just as much or slightly more feed per day in three of the four comparisons. The pigs fed the normal protein ration ate more feed daily than either of the other lots from weaning to 125 lb., and also consumed more feed during the later growth and fattening period than the low protein controls.

From weaning to an average weight of 125 lb. the 14.5 percent pro-

TABLE 2. GROWTH AND FEED RECORD OF PIGS FED A LOW PROTEIN RATION, A LOW PROTEIN RATION PLUS UREA AND A NORMAL PROTEIN RATION

Ration	From Weaning[1] to 125 Lbs.			From 125 to 200 Lbs.			From Weaning to 200 Lbs.		
	1	2	3	1	2	3	1	2	3
Treatment	Low protein	Low protein + urea	Normal protein	Low protein	Low protein + urea	Normal protein	Low protein	Low protein + urea	Normal protein
Crude protein level, %	10.6	13.6	14.5	10.0	11.7	10.6	—	—	—
				Average Daily Gain, Lbs.					
Replicate 1 (6 pigs)	1.16	1.27	1.48	1.68	1.70	1.83	1.34	1.40	1.62
2 (6 pigs)	1.36	1.22	1.54	1.74	1.74[2]	2.01[2]	1.52	1.53[2]	1.72
3 (5 pigs)	1.21	1.17	1.60	2.02	1.92	2.05	1.48	1.42	1.79
4 (6 pigs)	1.29	1.24	1.45	1.85	1.90	1.97	1.49	1.45	1.65
Average	1.26	1.22	1.52	1.82	1.82	1.96	1.46	1.45	1.70
				Average Daily Feed, Lbs.					
Replicate 1	4.0	4.2	4.4	6.8	8.0	6.8	5.0	5.4	5.3
2	3.9	4.3	4.9	6.9	6.1	7.8[2]	5.2	5.0	5.6
3	4.0	4.1	4.6	8.2	8.5	8.3	5.4	5.6	6.1
4	4.5	4.3	4.3	7.4	8.5	8.3	5.5	5.7	5.9
Average	4.1	4.2	4.6	7.3	7.8	7.8	5.3	5.4	5.7
				Feed Per 100 Lbs. Gain, Lbs.					
Replicate 1	345	332	298	406	471	373	372	382	330
2	288	356	319	398	418	329[2]	340	383	350
3	328	353	285	409	444	403	364	393	341
4	347	347	299	400	447	419	370	390	354
Average	327	347	300	403	445	396	362	387	344

[1] The average initial weights varied from 31 lb. in Replicate 4 to 40.5 lb. in Replicate 2 with an overall average of 34.6 lb.

[2] There were two subnormal pigs in the urea lot in Replicate 2, the growth data are for 4 pigs. One pig died in the normal protein lot, the data are for 5 pigs.

tein ration produced a lb. of gain with 9 percent less feed than the low protein ration. The latter ration was approximately 6 percent more efficient than the same ration with urea added. From 125 lb. to 200 lb. average weight there was less than 2 percent difference between the two control rations, but the urea-fed pigs required approximately 10 percent more feed per unit of gain than the low protein controls.

Under present conditions with respect to feed supplies it appears that added urea has no place in a ration for growing swine. This is in agreement with the reports of Ackerson *et al.* (1940) and Bice and Dean (1942) with chicks. Kriss and Marcy (1940) have concluded that urea is not utilized by the rat to any significant extent, when it is added to a maintenance ration. However, Rose *et al.* (1949) fed weanling rats a diet in which nearly all of the nitrogen was in the form of the ten essential amino acids. The addition of urea to this ration induced a marked acceleration in weight gains. Thus it is quite possible that pigs might use nitrogen from urea effectively if they were fed a ration relatively low in protein but containing sufficient quantities of the essential amino acids. Under practical conditions of feeding the limitations of low protein rations appear to be their deficiency in essential amino acids.

There was no clinical evidence in any of the trials, that urea had any toxic effect on the animals. The pigs fed added urea consumed an average of 28.6 gm. daily between weaning and a weight of 125 lb. and 35.4 gm. daily between weights of 125 to 200 lb. These urea consumption figures are similar to those reported by Piepenbrock (1927). Thus, cattle feeds containing low levels of urea (1.0—1.5%) can be fed to swine without risk of toxicity to the animals. The level of urea which a pig will tolerate was not determined in this experiment.

Summary

Sixty-nine pigs were fed to study the value of urea when added to a low protein ration for weanling pigs. The experiment consisted of three ration treatments. 1. a low protein ration, 2. the same ration plus urea, 3. a higher (normal) protein ration. Each treatment was replicated four times with 5 or 6 pigs per replicate.

The addition of 1.5 percent urea to a low protein (10.6%) ration for weanling pigs had no significant effect on daily feed consumption or rate of live weight gain. The pigs fed urea required 6 percent more feed per lb. of gain. Between weights of 125 to 200 lb., the pigs fed

the low protein ration with 1.0 percent urea added consumed 6.8 percent more feed daily than the pigs fed the low protein ration. However, live weight gains were the same for both rations and the urea-fed pigs required approximately 10 percent more feed per lb. of gain. There was no clinical evidence of toxicity at any time in any of the pigs fed urea.

The pigs fed the normal protein ration, 14.5 percent from weaning to 125 lb. and 10.6 percent from 125 to 200 lb. average weight, ate approximately 7.5 percent more feed daily, gained about 16 percent more per head daily and required 5 percent less feed per lb. of gain than the pigs fed the low protein control ration.

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PROTEIN NUTRITION AND THE UTILIZATION OF DIETARY PROTEIN AT DIFFERENT LEVELS OF INTAKE BY GROWING SWINE

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QUANTITATIVE studies of the body needs or utilization by the animal of a given nutrient may be considered the more precise the more specific are the criteria of adequacy and of utilization to the nutrient in question. Growth is not a specific criterion for any nutrient. For protein studies the nitrogen metabolism affords very specific criteria for use in measuring protein (or amino acid) requirements or metabolic utilization. In the experiment to be reported in this paper on protein utilization at different levels of intake, the conclusions will be based upon the nitrogen metabolism of growing pigs under conditions of dietary control, in accordance with the method developed in this laboratory (Mitchell, 1924) from the early studies of Thomas (1909) and used in prior experiments on pigs (Mitchell and Kick, 1927; Mitchell and Hamilton, 1931).

Although the method has been used rather widely in this country and abroad, its basic tenets have not gone unchallenged in recent years. The objection that the fecal nitrogen output on a nitrogen-free diet is not a reliable measure of the metabolic fecal nitrogen has been shown to be groundless for other animals than the mouse by Mitchell and Bert (1954), and evidence to the same effect will be offered in this paper for the pig.

The difficulty in measuring "valid" endogenous nitrogen outputs in the urine of pigs has been exaggerated by Bell and Loosli (1951) and Bell, Williams, Loosli and Maynard (1950), in the face of the earlier experiences of McCollum and Steenbock (1912) and of Smuts (1935). The pig is very adaptable to specific protein inanition, consuming enough food energy to increase in body weight over many weeks of feeding. It is true that in a condition of extreme protein depletion, the endogenous urinary nitrogen per m^2 of body surface is lower than in less depleted animals, but the endogenous urinary

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nitrogen is still valid for such conditions. In any event, it is not necessary to carry depletion to such extremes in determinations of the biological values of proteins. The additional criticism of direct determinations of the minimum endogenous urinary nitrogen put forward by the Cornell workers to the effect that "Nitrogen-free and nitrogen-low diets, if fed for the usual periods, are not compatible with normal growth" is gratuitous and irrelevant, since the measurement at issue does not pertain to growth anymore than does the basal expenditure of energy. Their decision to estimate the endogenous urinary nitrogen of their *growing* pigs by the use of the equation of Brody *et al.* (1934) based upon data secured with *mature* animals by the very methods criticized by them, is difficult to understand.

Notwithstanding these criticisms, the nitrogen balance method in the form developed in this laboratory has been applied in the experiments described below, to a study of (1) the relationship of the fecal nitrogen excretion per kilogram of dry matter consumed to the level of protein in the diet, (2) the relationship of the urinary nitrogen to the absorbed nitrogen, both expressed in grams per $W_{kg.}^{0.734}$, and (3) the relationship of the nitrogen balance to the absorbed nitrogen, both expressed in grams per $W_{kg.}^{0.734}$. The relationships secured will be compared with the same relationships secured in other similar experiments on growing pigs. Finally a brief review will be given of the published biological values of proteins secured with growing pigs as related to their contents of essential amino acids, and the degree to which such data for growing pigs agree with similar data for the albino rat and the dog.

Experimental Methods

The subjects of the experiments were six Hampshire pigs weighing initially from 20.6 to 25.7 kg.

The investigation was divided into five periods during the first and last of which each of the six pigs received a protein-free diet. During periods, two, three and four, the animals were fed on three different levels of protein (from a soybean meal), approximately 4 percent, 10 percent, and 16 percent. Two animals were given a particular protein level during each period, but the pairs getting the same levels of protein were not the same in each experimental period.

The metabolism trials were of 7 days duration each, and, with the exception of the first, were preceded by a preliminary feeding period

of at least 10 days; the first trial had only a 7-day prefeeding period. From the 8th day of the prefeeding period, daily urine collections were made for each of the animals and only when the level of nitrogen excretion had become constant did collections of urine and feces commence. While constancy of excretion was achieved, in the earlier trials by the 11th day, the prefeeding period in the later trials usually ran to 12–14 days.

TABLE 1. COMPOSITION OF RATIONS

Constituent	Nitrogen-free Diet	Soybean Diets		
		1. (4 Percent Protein)	2. (10 Percent Protein)	3 (16 Percent Protein)
	%	%	%	%
Soybean oil meal	—	8.65	21.20	33.62
Wood flock	10.26	9.88	8.35	6.98
Vitaminized starch[1]	4.79	4.94	4.86	4.81
Starch	37.01	31.62	27.19	22.13
Cerelose	33.56	30.64	25.25	20.20
Corn oil	6.23	6.36	6.17	6.01
Cod-liver oil	1.44	1.48	1.46	1.44
Wheat germ oil	0.48	0.49	0.49	0.48
Limestone	2.40	2.47	1.94	1.44
Bonemeal	2.40	1.98	1.65	1.44
Iodized salt	0.48	0.49	0.49	0.48
Salt Mix[2]	0.96	0.99	0.97	0.96

[1] Contains in grams per 100 lb., vitaminized starch; riboflavin, 2.5; thiamine, 2.5; pyridoxine, 2.5; calcium pantothenate, 20; nicotinamide, 10; para-aminobenzoic acid, 50; inositol, 100; and choline dry mix (Merck), 1000.

[2] Contains in grams; magnesium carbonate, 92; iron citrate ($3 \cdot H_2O$), 36; potassium citrate ($1\ H_2O$), 343; dipotassium phosphate, 146; copper sulfate ($5\ H_2O$), 0.4; manganous sulfate, 2.8; aluminum sulfate, 0.2; cobalt chloride ($6\ H_2O$), 0.1; sodium fluoride, 0.002.

The composition of the nitrogen-free and protein rations is given in table 1. The soybean meal used throughout these trials was a solvent-extracted product, heated to a temperature of 165° F. for 15 minutes. It contained 9.71 percent moisture, 45.78 percent protein (N x 6.25), 0.71 percent ether extract, 5.64 percent ash and 5.75 percent crude fiber. The proximate analysis of the rations is given in table 2. In all rations, levels of 6 percent crude fiber (wood flock was used to equalize the fiber content), 8 percent fat and 6 percent minerals were attempted. The protein-free diet did contain small quantities of nitrogen (0.12 percent), the principal source of which was the bone meal.

Feed levels equal to 5 percent of body weight raised to the power 0.90 were calculated for each pig at the commencement of each pre-

feeding period, and these levels were maintained constant throughout the prefeeding and collection periods.[3]

The animals, housed in metabolism cages described by Mitchell and Kick (1927), were fed twice daily, the feed being mixed with water to a thin slop. Feed residues, very rarely found, were fed back to the animal; those collected at the end of each trial were weighed after drying and the amounts deducted from the dryweights of feed offered.

TABLE 2. ANALYSIS OF RATIONS

Ration Designation	Protein (N x 6.25) %	Nitrogen %	Ether Extractives %	Crude Fibre %	Ash %	Nitrogen-free Extract %	Gross Energy Cals. per gm
Nitrogen-free diet	0.76	0.121	8.88	7.26	4.45	78.65	4101.
Soybean diet No. 1 (4 per-cent protein)	4.44	0.710	9.20	6.05	4.89	75.42	4127.
Soybean diet No. 2 (10 per-cent protein)	10.80	1.728	8.95	7.22	4.82	68.21	4329.
Soybean diet No. 3 (16 per-cent protein)	16.98	2.717	9.26	6.62	5.30	61.84	4450.

A feces marker (0.8 gm. ferric oxide per 100 gm. diet) was used. Feces samples collected daily were stored at 32° F. and the composite sample, after drying for 24–36 hours at about 120° F., was weighed, the hair removed, the residue ground and analyzed for nitrogen by the macro-Kjeldahl procedure. Urine samples were collected daily under toluene, made to volume and an aliquot taken to provide the composite sample to be used for analysis. The pigs were weighed at the beginning and end of each collection period.

Experimental Results

The individual experimental results are assembled in table 3.

With reference to the body weight changes of the pigs during the periods of 'nitrogen-free' feeding, it can be seen that, while in the first of the two periods, the animals showed no appreciable weight change—in the second period all gained in weight (average 2 kg.).

[3] During each collection period a small daily sample of feed was taken and the composite sample at the end of the period used for analysis. Moisture contents of each ration at the beginning and end of all trials were also determined.

TABLE 3. THE NITROGEN METABOLISM DATA FOR THE INDIVIDUAL PIGS

Pig No.	Period	Mean Body Weight Kg.	Total Gain in Weight in 7 Days Kg.	Dry Feed Consumed Daily Kg.	Nitrogen Metabolism Per Day				Nitrogen Metabolism Per Day Per $W_{Kg.}^{0.734}$			Fecal N per Kg. Dry Feed Gm.
					Intake Gm.	Feces Gm.	Urine Gm.	Balance Gm.	Absorbed[1] Gm.	Urine Gm.	Balance Gm.	
					Low-Protein Ration							
2	1	20.54	0.68	0.658	0.80	0.77	1.25	−1.22	0.087	0.136	−0.133	1.178
3	1	25.20	−0.45	0.733	0.89	0.81	1.41	−1.34	0.084	0.132	−0.125	1.112
4	1	23.27	0.68	0.808	0.98	0.84	1.25	−1.12	0.098	0.124	−0.111	1.044
5	1	23.84	0	0.739	0.89	1.50	2.79	−3.40	0.088	0.272	−0.331	2.033
6	1	20.66	0	0.677	0.82	0.72	1.24	−1.14	0.089	0.134	−0.123	1.071
					Approximately 4 Percent Protein Ration							
1	3	33.60	1.81	0.929	6.74	1.14	3.57	+2.03	0.486	0.269	+0.154	1.22
2	2	23.63	0.95	0.670	4.75	1.07	2.02	+1.66	0.438	0.199	+0.163	1.59
3	2	28.89	1.47	0.781	5.55	1.38	2.29	+1.88	0.424	0.194	+0.159	1.76
4	3	32.01	0.36	0.873	6.33	1.34	2.35	+2.64	0.475	0.185	+0.207	1.54
5	4	42.45	2.27	1.112	8.30	1.33	3.62	+3.36	0.532	0.231	+0.215	1.20
6	4	37.23	1.82	1.000	7.47	1.47	3.29	+2.72	0.505	0.231	+0.191	1.47
					Approximately 10 Percent Protein Ration							
1	4	42.22	2.72	1.056	19.82	2.02	7.03	+10.77	1.200	0.450	+0.691	1.91
2	3	29.40	2.04	0.760	12.44	1.77	3.80	+6.87	0.963	0.318	+0.574	2.34
3	4	46.88	3.42	1.148	21.56	2.76	6.42	+12.37	1.181	0.381	+0.734	2.40
4	2	27.36	2.05	0.741	12.80	2.14	3.40	+7.26	1.014	0.300	+0.641	2.89
5	2	27.92	1.82	0.741	12.80	1.67	4.61	+6.52	1.080	0.401	+0.566	2.25
6	3	32.01	2.47	0.834	13.66	1.66	5.01	+6.98	1.016	0.394	+0.549	2.00
					Approximately 16 Percent Protein Ration							
1	2	29.11	2.38	0.738	20.06	2.26	7.25	+10.55	1.55	0.610	+0.888	3.06
2	4	39.16	3.40	0.926	25.76	2.63	8.25	+14.88	1.64	0.559	+1.007	2.83
3	3	37.46	3.17	0.911	23.92	2.74	7.63	+13.55	1.55	0.534	+0.948	3.01
4	4	41.43	2.95	0.982	27.30	3.33	9.34	+14.63	1.64	0.607	+0.951	3.39
5	3	35.75	2.95	0.874	22.94	2.47	9.76	+10.71	1.58	0.707	+0.776	2.82
6	2	26.05	2.16	0.665	18.06	2.05	5.84	+10.17	1.53	0.534	+0.930	3.09
					Low-Protein Ration							
1	5	48.46	2.05	1.273	1.54	1.11	1.30	−0.86	0.090	0.070	−0.050	0.870
2	5	43.92	2.05	1.199	1.45	1.29	1.34	−1.17	0.091	0.083	−0.073	1.070
3	5	53.00	1.59	1.388	1.68	1.26	1.58	−1.15	0.092	0.086	−0.063	0.910
4	5	47.10	2.04	1.255	1.52	1.71	3.23	−3.41	0.090	0.191	−0.202	1.363
5	5	48.69	2.50	1.273	1.54	1.21	1.53	−1.19	0.089	0.088	−0.068	0.948
6	5	42.22	1.82	1.126	1.36	1.36	1.80	−1.79	0.088	0.116	−0.115	1.207

[1] Truly absorbed nitrogen, taking account of the metabolic fecal nitrogen.

During the intervening protein-feeding periods the gains in weight increased with increasing protein content of the diet, the increases ranging from an average of 1.45 kg. per 7 days on the 4-percent level of dietary protein to 2.84 kg. on the 16-percent level.

The mean value for metabolic fecal nitrogen determined during the the first 'nitrogen-free' feeding period is 1.288 ± 0.168 gm. per kg. dry matter consumed; the individual values ranging from 1.044 to 1.178 except for a value of 2.033. From the second period of feeding a 'nitrogen-free' diet, the mean metabolic fecal nitrogen value found is $1.062 \pm .072$ gm. per kg. of dry matter consumed. Statistical examination of the two sets of data by the 'Student' method for paired results (1925) shows that the differences are not significant and, therefore, all results have been pooled; the mean of the combined data is 1.140 gm. per 1000 gm. dry matter consumed.

The average data obtained for the fecal nitrogen excretion per kg. of dry matter consumed (y) during the five feeding periods have been plotted against the protein contents of the diets on the dry basis (x) in Figure 1. From the data obtained in feeding the protein-containing diets a linear equation $y = .1252x + .9100$ has been fitted by the method of least squares. By extrapolation of the regression to zero protein intake a value for metabolic fecal nitrogen of 0.91 gm. per kg. dry matter consumed is obtained. The mean value for the nitrogen content of feces of pigs fed the low-nitrogen diet in these experiments, containing 0.76 percent conventional protein, is 1.165 gm. per kg. of dry matter consumed, while solution of the regression equation above given for $x = 0.76$, gives a value of y of 1.005 gm. of fecal nitrogen per kg. of dry matter consumed. When a statistical examination of the line variance at $x = 0.76$ and of the variance of the mean of the values obtained by feeding a low-nitrogen diet is made, no significant difference is found to exist between the two values. Thus, one may consider the mean of the values for metabolic fecal nitrogen directly determined, as belonging to the population represented by the line $y = 0.1252x + .9100$.

It would, therefore, appear reasonable to conclude that both methods used in this investigation, viz., that of feeding an almost nitrogen-free diet, or that of extrapolation to zero nitrogen intake of a linear relationship between feed nitrogen and fecal nitrogen determined at increasing levels of protein intake, give essentially the same mean results, although the direct determination is obviously more economical of time and labor.

The mean value for endogenous urinary nitrogen excretion for the first of the two periods of 'nitrogen-free' feeding is 159.7 mg. per $W_{kg.}^{0.734}$, and for the second period, 106.6 mg. on the same basis. Statisti-

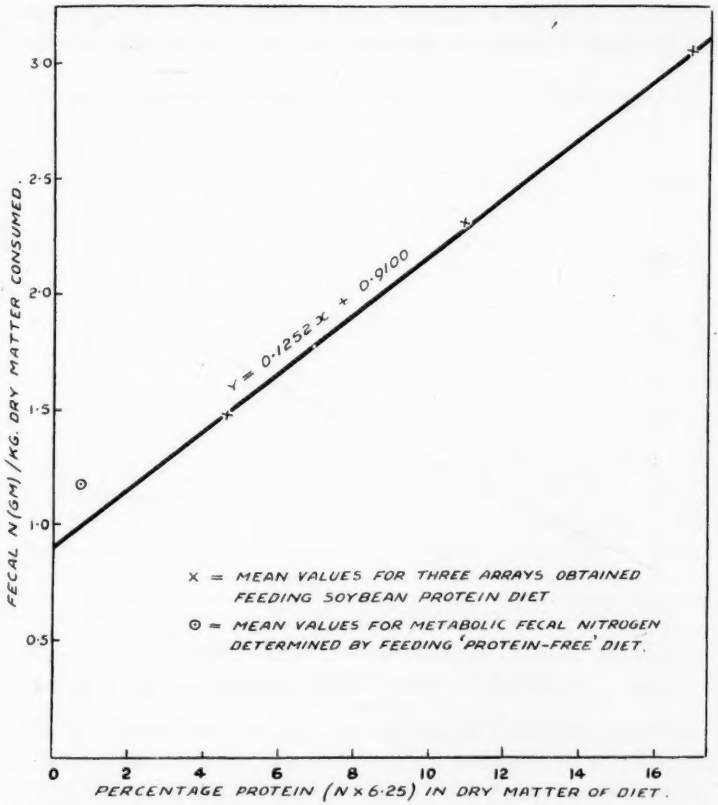

Figure 1. Relationship between fecal nitrogen (y) and level of protein in feed (x).

cal examination of the two sets of results by the "Student" (1925) technic for paired data showed no significant difference and therefore all results were grouped giving a mean of 133.1 mg. per $W_{kg.}^{0.734}$.

In figure 2, the average urinary nitrogen excretion is plotted against the average truly absorbed nitrogen, giving due consideration to the

metabolic fecal nitrogen, all values being reduced to $W_{kg.}^{0.734}$ to eliminate as far as possible the influence of differences in body weight, W, between different pigs and different periods (Brody and Proctor, 1932). The relationship is quite evidently a linear one except for the 16 percent protein level which was not considered in fitting the regression equation to the data. Evidently at this high level of protein intake, dietary

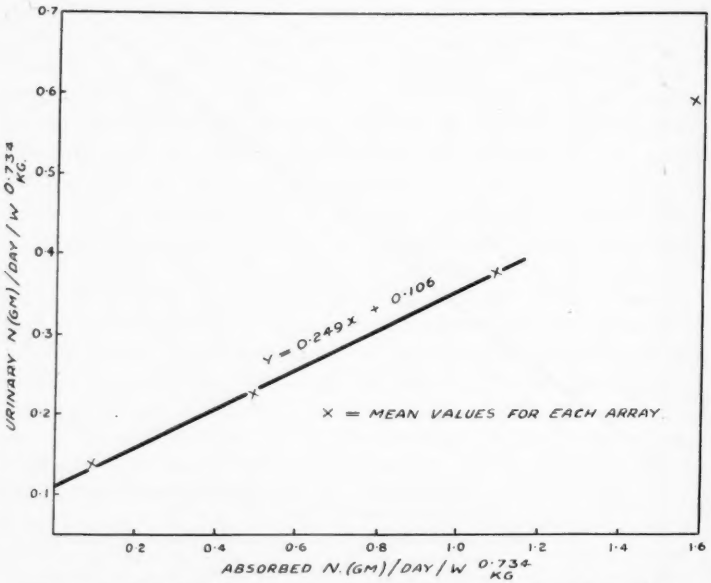

Figure 2. Relationship between urinary nitrogen (y) and absorbed nitrogen (x).

protein is being consumed in excess of current needs with an increase in urinary nitrogen unrelated to protein utilization in anabolism.

In figure 3, the mean values for nitrogen balance of all of the animals in all five periods are plotted against those for truly absorbed nitrogen (N intake—(total fecal N—metabolic fecal N)). The relationship is a linear one except for the highest protein period, evidently representing a condition of excess protein nutrition. The coefficient of x in the regression equation, 0.7615, is the nitrogen balance index of Allison and Anderson (1945).

In order to measure the degree of protein depletion produced in

pigs by protein-free feeding, the concentration of blood plasma proteins was measured in four of the pigs (Nos. 1, 2, 3 and 5) following the final period of the experiment, using the falling drop method of Barbour *et al.* (1926) and taking blood samples from the anterior vena cava. The values secured on the 31st day of depletion were 5.73, 5.90 and 5.76 gm. per 100 ml. of plasma for pigs 1, 3 and 5. The

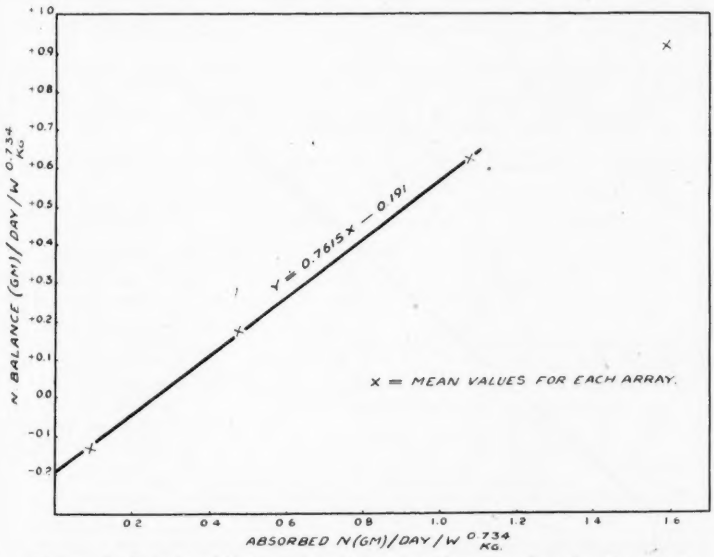

Figure 3. Relationship between nitrogen balance and truly absorbed nitrogen.

value of 6.24 secured with pig 2 was associated with slight hemolysis of the sample.

No information was found in the literature concerning the concentration of protein in the blood plasma of undepleted pigs beyond weaning age. An early reference (Bächer and Kosian, 1924) gives the total protein concentration of the blood serum of pigs as 6.30 gm. per 100 ml. This may be converted to plasma protein concentration if it may be assumed, as seems justifiable (Parfentjev *et al.*, 1953), that the average fibrinogen content of normal plasma is relatively constant at 0.25 gm. per 100 ml. Thus, the concentration of total proteins in the blood plasma of pigs may be placed at 6.55 gm. percent. Because of the

uncertainty residing in this value, and the few data upon which it is based (only 3 pigs), determinations were made by the falling drop method of the total protein in the plasma of six normal Chester White pigs weighing about 100 lb., which were carried out by Dr. V. Chalam Metta, to whom the authors express their great appreciation. The average value obtained with its standard error was 6.52 ± 0.14 gm. per 100 ml., or 6.33 ± 0.12, when two blood samples in which slight

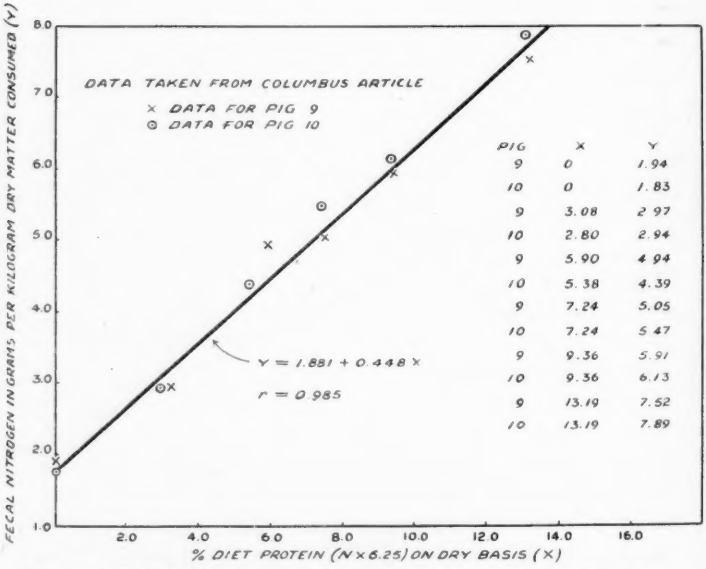
FECAL NITROGEN IN GRAMS PER KILOGRAM DRY MATTER CONSUMED (Y)
% DIET PROTEIN (N×6.25) ON DRY BASIS (X)
DATA TAKEN FROM COLUMBUS ARTICLE
× DATA FOR PIG 9
⊙ DATA FOR PIG 10
Y = 1.881 + 0.448 X
r = 0.985
PIG X Y
9 0 1.94
10 0 1.83
9 3.08 2.97
10 2.80 2.94
9 5.90 4.94
10 5.38 4.39
9 7.24 5.05
10 7.24 5.47
9 9.36 5.91
10 9.36 6.13
9 13.19 7.52
10 13.19 7.89

Figure 4. Relationship between fecal nitrogen (y) and percent dietary protein (x) in Columbus' experiment on pigs.

hemolysis occurred are disregarded. The latter average is much the same as the values reported by Reber, Whitehair and MacVicar (1953) for baby pigs, i.e., 5.7 to 6.3.

It may be pointed out that the slight degree of hypoproteinemia developed in the experimental pigs after 31 days of protein depletion, represented by the difference in average concentration of plasma protein in the undepleted animal, 6.33 gm. per 100 ml., and in the depleted animal, 5.80 gm. per 100 ml., is much less than that associated with abnormal nitrogen balance indices in Allison's (1946) experiments on

dogs. In these experiments the plasma protein level fell from a range of 5.6 to 7.1 gm. percent to a range of 4.0 to 4.5 gm. percent.

Discussion

The existence of a linear relationship between the nitrogen content of the diet and the output of this element in the feces was demonstrated for the pig for levels of nitrogen above about 15 gm. per kg. of dry matter (equivalent to 8.7 percent protein in the diet) by Bell

TABLE 4. THE METABOLIC FECAL NITROGEN PER UNIT OF DRY MATTER CONSUMED FOR GROWING SWINE. AVAILABLE INFORMATION

Method of Determination or Estimation	Metabolic Fecal Nitrogen in gm. per kg. Dry Matter Consumed	Authority
Compilation from literature	2.0	Mitchell (1926)
Direct determination	0.96	Schiftan (1932)
Regression analysis[1]	0.63	Schneider (1935)
Regression analysis[2]	1.8	Bell *et al.* (1950)
Direct determination	1.10	Mitchell and Hamilton (1931)
Direct determination	0.92	Mitchell and Kick (1927)
Direct determination	0.76	Mitchell and Hamilton (1933)
Regression analysis[3]	1.88	Columbus (1950)
Regression analysis[4]	0.91	This paper
Direct determination	0.95	Columbus (1950)

[1] Slope of the regression equation of fecal N on N-free dry matter consumed.
[2] Wide extrapolation of regression equation of fecal N per kg. dry matter consumed on N intake.
[3] Intercept of regression equation of fecal N per kg. dry matter consumed on protein content of diet. See figure 4 of this paper.
[4] Intercept of regression equation of fecal N per kg. dry matter consumed on protein content of diet. See figure 1.

et al. (1950), and by Mitchell and Bert (1954) for several species of animals from practically zero intake of nitrogen to high levels. The average data plotted in figure 1 establish the rectilinearity of this relationship for the growing pig, while the individual data on two growing pigs fed different levels of fishmeal nitrogen, taken from the experiments of Columbus (1950) and presented graphically in figure 4, possess the same significance.

The values reported by different investigators for the metabolic fecal nitrogen per kg. of dry matter consumed for the pig are so variable as to indicate the operation of unidentified contributing factors. The available data have been assembled in table 4.

Possible causes of the variation in the results reported in this table

are: differences in body weight of animal (Schneider, 1934) and in such dietary factors as crude fiber (Mitchell, 1924), especially when intestinal motility is considerably increased (Adolph and Wu, 1934); minerals may exert a similar effect. The alimentary ballast, as measured by the volume of feces (Mendel and Fine, 1912) or the fecal dry matter (Heupke, 1933; Mukherjee and Kehar, 1949, may be an important factor, but even under conditions as constant as can be imposed, a variable output of metabolic fecal nitrogen has been observed (Toscani and Whedon (1951). Certainly no average value secured with one group of pigs under one set of dietary conditions can be applied to other pigs under other conditions with any assurance of success.

The regression of urinary nitrogen on truly absorbed nitrogen, both variates being expressed to $W_{kg.}^{0.734}$ to permit pooling of data for animals of different body weights (Brody and Proctor, 1932), is evidently rectilinear from 0 to 10 percent dietary protein, or somewhat higher levels (see figure 2). The intercept of the regression line on the y axis is 0.106. This value is the estimated minimum endogenous urinary nitrogen in grams per day per $W_{kg.}^{0.734}$. It is a value that will vary with age in a manner similar to the basal metabolic rate (Ackerson, Blish and Mussehl, 1923; Blaxter and Wood, 1951). In early maturity it is related to the basal metabolism, in several species of animals besides the pig, in such a manner that 2 mg. of endogenous urinary nitrogen (minimum) are excreted per basal calorie (Smuts, 1935). Age will disturb the constancy of this ratio, the young animal as well as the old animal exhibiting a lower ratio (Treichler, 1939). Estimating the basal metabolism of pigs weighing 23 and 47 kg., the average weights of the pigs in this experiment during the initial and final periods when the low-nitrogen diet was fed, by the equation given by Brody, Ragsdale and Trowbridge (1932) to describe the change in basal metabolism with age of the castrated male pigs studied by Deighton, the ratios of endogenous urinary N to basal heat are 1.27 and 1.23 mg. per cal., respectively. These values are to be compared with that of 2.10 mg. per cal. observed by Smuts for much larger pigs.

The relationship of the mean nitrogen balance to the mean truly absorbed nitrogen (making due allowance for the metabolic nitrogen in the feces) for the pigs in this experiment fed different levels of soybean meal, is a linear one through the level of 10 percent conventional protein. The value secured at a level of 16 percent protein is evidently low, indicating a departure from linearity somewhere in the interval between the 10 percent and 16 percent levels, as a result of

feeding an amount of protein in excess of the ability of the animal to synthesize tissue protein. The situation is quite similar to that reported by Allison and Anderson (1945), who observed with adult dogs a linear relationhip between nitrogen balance and absorbed nitrogen in the region of negative nitrogen balances and of low positive balances, but a departure from linearity at high levels of absorbed nitrogen.

The constant in the regression equation, 0.191, represents the grams of nitrogen excreted in both urine and feces per $W_{kg.}^{0.734}$ when the nitrogen intake is zero but the energy intake is adequate. The coefficient of x, 0.7615, when multiplied by 100, is the average biological value [4] of the protein (nitrogen) of soybean meal over a range of intake up to 10 percent. This value of 76 is to be compared with the value of 73 reported for growing swine by Columbus (1950) at a level of about 8 percent dietary protein, and the value of 80 reported by Bell *et al.* (1950) secured with growing pigs at a level of dietary protein of 10.5 percent. The latter value involved the estimation, rather than the determination, of the contribution of the body to the nitrogen of the feces and of the urine.

The rectilinearity of the regression of biological value on absorbed nitrogen from 0 to a certain critical level of absorbed nitrogen, not precisely determined in this experiment, but evidently different for proteins of different nutritional quality, shows that within these limits the metabolic utilization of dietary protein is constant. Above this critical level of absorbed nitrogen, the biological values may be considered as spurious, since they are adversely affected by the influx of amino acids from the intestinal tract in amounts exceeding current needs.

The same situation is revealed by the nitrogen metabolism data of Columbus (1950) on two growing pigs receiving increasing levels of

[4] Using Allison's symbols, the regression lime may be represented by the following equation:

$$NB = K(AN) - NE_o \qquad (1)$$

in which NB is the nitrogen balance, AN the truly absorbed N, and NE_o is the nitrogen excretion on a protein-free diet, and is in turn equal to the metabolic fecal nitrogen, MFN, plus the minimum endogenous urinary nitrogen, EN; K is Allison's "nitrogen balance index" and in animals with normal protein stores it may be taken as the biological value, BV, of the truly absorbed N, AN.

Therefore, the above equation may be rewritten

$$K = \frac{NB + MFN + EN}{AN} = BV \qquad (2)$$

The biological value, B.V., is ordinarily defined as follows:

$$BV = \frac{NI - (FN - MFN) - (UN - EN)}{NI - (FN - MFN)} \qquad (3)$$

in which NI is the nitrogen intake, FN the fecal N and UN the urinary N. The denominator of the fraction in equation (3) is equal to AN; in the numerator NB=NI−FN−UN. Hence, equation (3) reduces to equation (2).

dietary nitrogen as fishmeal. These findings are plotted in figure 5. The variates are related in a rectilinear fashion up to an intake of absorbed nitrogen of 0.64 grams per $W^{0.734}_{kg.}$, equivalent to a dietary protein level of 9.36 percent on the dry basis. Above this level the biological values may be considered spurious for the reason above given. The critical level of absorbed nitrogen is lower in this experiment than in that indicated in figure 3, in accordance with the higher biological valu of fishmeal proteins, 89, than of soybean meal proteins, 74.

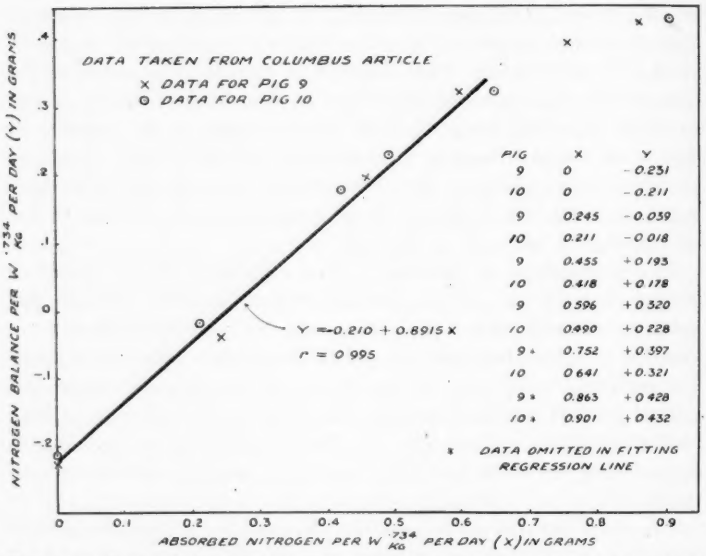
DATA TAKEN FROM COLUMBUS ARTICLE
× DATA FOR PIG 9
⊙ DATA FOR PIG 10
Y = -0.210 + 0.8915 x
r = 0.995
PIG X Y
9 0 -0.231
10 0 -0.211
9 0.245 -0.039
10 0.211 -0.018
9 0.455 +0.193
10 0.418 +0.178
9 0.596 +0.320
10 0.490 +0.228
9 * 0.752 +0.397
10 0.641 +0.321
9 * 0.863 +0.428
10 * 0.901 +0.432
* DATA OMITTED IN FITTING REGRESSION LINE
NITROGEN BALANCE PER W^.734 KG PER DAY (Y) IN GRAMS
ABSORBED NITROGEN PER W^.734 KG PER DAY (X) IN GRAMS
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
.4 .3 .2 .1 0 -.1 -.2

Figure 5. The relationship between nitrogen balance (y) and absorbed nitrogen (x) in Columbus' experiment on pigs.

In analyzing his own data, Columbus deduces a negative correlation of biological value on nitrogen intake expressed as a multiple of the maintenance nitrogen requirement (endogenous N+metabolic fecal N), using in his analysis all of the data. The individual data are quite irregular and the correlation deduced may have been determined by the inclusion of spurious biological values associated with intakes of nitrogen exceeding current requirements. The same criticism may be applicable to prior publications from this laboratory (Mitchell, 1924; Mitchell and Beadles, 1927), indicating a lowered biological value of

dietary protein as the level of intake is increased. The necessity of a statistical analysis of such data to establish the reality of average differences in biological values obtained at different levels of intake is obvious.

The biological values of feed proteins that have been made for swine by the nitrogen balance method are few, particularly in this country.

TABLE 5. THE BIOLOGICAL VALUES OF FEED PROTEINS FOR GROWING PIGS AS COMPARED WITH THE CORRESPONDING ESSENTIAL AMINO ACID INDICES BY MODIFIED OSER METHOD

Feed	Biological Value %	Essential Amino Acid Index[1] %	Authority for Biological Data[2]
Cow's milk	95	94	Schiftan (1932)
Cow's milk	97	94	Ganchev and Popov (1936)
Casein	82	93	Schiftan (1932)
Fishmeal	78	87	Nehring and Schramm (1940)
Fishmeal	74	87	Schiftan (1932)
Fishmeal	89	87	Columbus (1950)
Soybean meal	73	84	Columbus (1950)
Soybean meal	76	84	This paper
Cottonseed meal	63	69	Mitchell and Hamilton (1931)
Linseed meal	61	69	Mitchell and Hamilton (1931)
Corn	61	71	Mitchell and Hamilton (1931)
Corn	49	71	Ganchev and Popov (1936)
Corn	54	71	Mitchell and Kick (1927)
Barley	57	55	Nehring and Schramm (1940)
Barley	71	55	Schiftan (1932)
Pea	65	68	Ganchev and Popov (1936)
Pea	62	68	Columbus (1950)
Lupine seed, white	67	60	Columbus (1950)

[1] Modified Oser method (see Table 6).
[2] The chemical data from which the essential amino acid indices were computed were, with few exceptions, taken from Block and Bolling (1951).

It is important to consider briefly the question first, whether the many determinations made with rats are applicable to growing pigs, and, second, whether the biological values of proteins are as closely related to the essential amino acid content with swine as they are with rats (Mitchell and Block, 1946; Oser, 1951). In table 5, are assembled such information on those feeds for which biological values and adequate amino acid analyses for the computation of essential amino acid indices, are available. The amino acid indices have been computed by the method of Oser modified by the elimination of arginine

from the calculation, by the treatment of tyrosine and phenylalanine in an analogous manner to the treatment accorded cystine and methionine, and by crediting a protein with no more tyrosine and cystine than is contained in the reference protein mixture, that of whole egg. The revised method of computation is illustrated for lactalbumin in table 6.

TABLE 6. COMPUTATION OF MODIFIED ESSENTIAL AMINO ACID INDEX

Amino Acids	Amino Acid Content per 16 gm. Nitrogen		Egg Ratio	Corrected Ratios	Logarithms of Corrected Ratios
	Whole Egg Protein	Lactalbumin			
	gm.	gm.	%	%	
Histidine	2.4	2.3	96	96	1.98227
Lysine	7.0	10.5	150	100	2.00000
Phenylalanine	6.3	5.0	79		
Tyrosine	4.5	5.3	118		
Phenylalanine plus tyrosine	10.8	10.3	95	88	1.94448
Tryptophane	1.5	2.5	167	100	2.00000
Methionine	4.0	2.6	65		
Cystine	2.4	4.0	167		
Methionine plus cystine	6.4	6.6	103	78	1.89209
Threonine	4.3	6.0	140	100	2.00000
Leucine	9.2	12.1	132	100	2.00000
Isoleucine	7.7	7.5	97	97	1.98677
Valine	7.2	6.6	92	92	1.96379
Average logarithm					1.97438
Modified essential amino acid index					94

The biological and chemical data in table 5 are highly correlated, the coefficient of correlation being +0.77. The regression of biological value (y) on essential amino acid index (x) is rectilinear and is well described by the equation $y=9.9+0.802\ x$.

One of the authors elsewhere (Mitchell, 1954) has presented a similar analysis of a series of 48 pairs of data, mainly secured with rats, but including data on pigs (7) and dogs (8). The data for all animals seemed to be homogeneous and exhibited a high correlation of the biological values (y) and essential amino acid indices (x), with $r=+0.95$. The regression was linear and the regression equation was $y=-13.74+1.075\ x$.

Comparison of the two regression equations statistically reveals that the regression coefficients, 0.802 and 1.075, are not statistically distinguishable.

The conclusion seems justified, therefore, that the utilization of dietary protein in metabolism by rats, pigs and dogs, is essentially similar, and quite probably this conclusion may be extended to all monogastric mammals. This is not a matter of surprise because of the known, and generally striking, similarity in the amino acid contents of the tissues being formed during growth (Beach, Munks and Robinson, 1943; Dunn *et al.*, 1949), and the probable similarity in the processes of protein biosynthesis among different species of animals.

Summary and Conclusions

Six Hampshire pigs, weighing initially from 21 to 27 kg., were carried through five nitrogen metabolism periods on three different levels of the same protein mixture (soybean meal), approximately 4, 10 and 16 percent, and on two low-nitrogen standardizing diets, in periods 1 and 5, for the purpose of measuring the biological value of the protein at different levels of intake.

The pig is readily adaptable to a very low-nitrogen diet, gaining in body weight for many weeks with the development of only a slight degree of hypoproteinemia.

The fecal nitrogen output of the growing pig is linearly related to the protein level of the diet fed (on the dry basis), over a range of practically zero to 16 percent. Under the conditions of this experiment, the metabolic fecal nitrogen (the intercept of the regression line on the ordinate) was 0.91 gm. per kg. of dry matter consumed.

The regression of urinary nitrogen on truly absorbed nitrogen, both variates being expressed to $W_{kg.}^{0.734}$ to permit pooling of the data for differences in body weight, is evidently rectilinear from 0 to 10 percent of protein, or somewhat higher. The intercept of the regression line on the ordinate, 106 mg. urinary N per $W_{kg.}^{0.734}$, is the minimum endogenous urinary nitrogen output per day.

The relationship of the nitrogen balance to the truly absorbed nitrogen, expressed in grams per $W_{kg.}^{0.734}$, is rectilinear up to a protein level of 10 percent or more. The departure from linearity at higher levels of dietary protein is due to the consumption of amounts of protein in excess of current needs.

The slope of the regression line expressed as a percentage is 76 and, under the conditions of this experiment, may be taken as the biological

value of the protein in the particular sample of soybean meal used in this experiment. The constant slope of the regression line up to a level where dietary protein is being consumed in excess of current requirements, means that within this range of protein intake the percentage of protein in the diet has no effect upon the metabolic utilization of protein.

The range of dietary protein intake within which metabolic utilization of protein (biological value) is constant, will be the narrower the higher the biological value.

Evidence is presented from this study and from the literature supporting the thesis that the metabolic utilization of dietary proteins among monogastric mammals is the same and is related to the same degree to the contents of the essential amino acids (plus tyrosine and cystine) in any particular protein or protein mixture.

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DIFFERENT PROTEIN LEVELS WITH AND WITHOUT ANTIBIOTICS FOR GROWING-FINISHING SWINE: EFFECT ON GROWTH RATE AND FEED EFFICIENCY [1, 2, 3]

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CATRON *et al.* (1952) reported satisfactory growth and feed efficiency in swine fed corn-soybean oil meal rations fortified with vitamins and minerals which were lower in protein than previously recommended. In the absence of aureomycin, a 16–13–10 percent protein level combination fed from weaning to 75, 75 to 150 and 150 to 200 pounds supplied the pigs' needs for protein; whereas, in the presence of the antibiotic, a 14–11–8 percent level combination produced uniform results equivalent to higher levels of protein with or without antibiotic. Some looseness was observed in the pigs fed a high protein combination (20–17–14 percent) without aureomycin but not with it. Aureomycin apparently effected more efficient protein utilization at the lower protein levels. This is in agreement with the earlier findings of Cunha *et al.* (1950) who reported that an animal protein factor supplement containing aureomycin, lowered the protein needs of pigs.

Bowland *et al.* (1952, 1953) reported one experiment indicating that aureomycin lowered the protein requirement, but in a subsequent experiment no such effect was observed by feeding penicillin. Robison (1952) obtained faster, more efficient gains in pigs fed a 12.4 percent protein ration from 45 to 120 lb. and a 10.4 percent ration from 120 to 210

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[3] The terms aureomycin and terramycin are used to refer to chlortetracycline and oxytetracycline respectively throughout this manuscript.

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lb., both rations containing 7.5 milligrams of aureomycin per lb., than in similar pigs fed 18.2 and 16.3 percent protein rations during the same weight intervals without antibiotic.

Meade (1952) reported an experiment on pigs fed from weaning to 200 lbs. on a balanced ration in which the protein level was dropped 2 percentage units at 75 and at 125 pounds. A 14–12–10 percent protein combination gave faster growth when 2 or 8 milligrams of aureomycin per lb. of ration was fed than 18–16–14 or 16–14–12 percent protein combinations without antibiotics. Confirmation of this antibiotic effect on protein level has been reported by Botkin and associates (1951), Hoefer *et al.* (1952), and by Beeson and Conrad (1952).

Investigations conducted by Becker *et al.* (1953), Terrill and coworkers (1952), Mertz and associates (1952) and Burnside *et al.* (1954) have shown that protein levels lower than those previously recommended produce satisfactory pig performance.

The two experiments reported herein were conducted to obtain further information on the protein requirements of growing-finishing swine fed in concrete drylot, and to study the effect of antibiotics, aureomycin or terramycin, on this requirement. This was a cooperative study between the swine nutrition section of the Animal Husbandry Department and the Agricultural Economics Department. A report on the effects of protein levels and antibiotics on carcass measurements of these pigs will be reported separately, (Ashton *et al.*, 1955).

Experimental Procedure

Experiment 536

In each of two replicates, 18 ration treatments were assigned at random to 18 lots of four pigs each. The 72 pigs in each replicate were grouped into four weight brackets and one pig from each weight bracket was randomly assigned to a lot within the replicate.

The pigs within each replicate were selected for uniformity with respect to previous treatment, breeding, and condition. The lots in the first replicate contained two Duroc and two cross-bred (Poland China x Landrace x Duroc) pigs while the second replicate consisted entirely of cross-breds. The pigs were from sows which had been fed a fortified plant-protein ration during lactation in concrete drylot. Average starting weights on the various treatments ranged from 35 to 37 pounds per pig and the average initial age of the pigs was 57 days.

The pigs were wormed with a 0.5 percent sodium fluoride ration for

2 days and then sprayed with benzene hexachloride for external parasite control before going on experiment. Feed and water were allowed *ad libitum* and the pigs were confined to indoor concrete pens during the entire feeding period. The pigs were weighed individually and the feed of each lot of pigs was weighed back every two weeks. Each pig was individually removed from the experiment at a weight of approximately 200 lbs.

Protein levels of 10, 12, 14, 16, 18 and 20 percent were fed to each of six replicated lots of pigs from an initial weight of approximately 36 lbs. to a termination weight of 200 lbs. In contrast to general practice, the protein levels were held constant throughout the entire feeding period in both experiments 536 and 554. This was done to facilitate a study concerned with the determination of a production function relating pig gains to the protein level of the ration fed. This involved fitting prediction equations to the data on the basis of the relative substitution values for each other of corn and soybean oil meal in the ration for hogs of different weights. This aspect was of primary interest to the Agricultural Economics Department. Two of the six lots on each protein level received no antibiotic, two received 5 mg. of aureomycin hydrochloride, and two received 5 mg. of terramycin hydrochloride per lb. of ration.

The rations contained ground yellow corn, solvent soybean oil meal (a blend of three manufacturers' hexane solvent extracted meals), steamed bone meal, calcium arbonate, a trace mineral mixture, iodized salt, and a vitamin premix. The vitamin content of the premix was adjusted for the various protein levels so that the calculated vitamin content of the complete rations was as follows: 2000 I.U. vitamin A, 400 I.U. vitamin D_2, 1.5 mg. riboflavin, 20 mg. niacin, 5 mg. pantothenic acid, 500 mg. choline chloride, 0.5 mg. folic acid, 1.0 mg. pyridoxine, 1.0 mg. thiamin HCl, and 5 mcg. vitamin B_{12} per lb. The trace mineral mixture contributed to the ration, in ppm.; iron 70, copper 4.8, cobalt 1.6, manganese 59, and zinc, 4.4.

The various protein levels were obtained by shifting the proportions of corn and soybean oil meal according to their chemical analyses. The calculated calcium and phosphorus contents of 1.0 percent and 0.7 percent, respectively, were held constant by adjusting the amounts of steamed bonemeal and calcium carbonate. The rations were calulated to contain 10, 12, 14, 16, 18 and 20 percent protein; they analyzed 9.8, 12.3, 14.3, 15.9, 17.3 and 20.0 percent, respectively.

Experiment 554

The design of this experiment was the same as that of the first, except that aureomycin hydrochloride was the only antibiotic included. There were three replicate lots of pigs on each of the six protein levels, with and without aureomycin, making a total of three lots (of four pigs each) on all 12 ration treatments.

As before, the pigs (from outcome groups) and the treatments were allotted to the lots at random. The pigs for each replicate were selected for uniformity in breeding, condition and sex. There were two barrows and two gilts in each lot. In each of two replicates 48 cross-bred pigs (Poland China x Landrace x Duroc) were used and in the third replicate 48 Durocs were used.

Average starting weights on the various ration treatments ranged from 30 to 32 pounds per pig. The pigs averaged 54.5 days of age initially. Each pig was removed as it reached a weight of approximately 200 lbs. Disease control, management, and weighing practices were the same as in the previous experiment.

The ration ingredients and the calculated vitamin content of the rations for Experiment 554 were the same as those in Experiment 536, with the following exceptions: 2500 I.U. vitamin A and 450 mg. choline chloride were included per lb. of ration. Calculated calcium and phosphorus levels were 0.75 and 0.5 percent. Representative samples of the 12 rations were analyzed for protein with the following results in order of increasing protein content: without aureomycin, 10.8, 12.4, 13.9, 15.7, 18.6 and 20.7 percent, and with aureomycin, 10.6, 12.3, 14.5, 16.0, 18.9 and 22.4 percent. The data of the two experiments were analyzed according to the analyses of variance schemes presented in table 1. All differences indicated as significant throughout the manuscript are at $P=0.05$ or less.

Results

Experiment 536

A summary of the average daily gains and the average feed efficiencies for the growth periods from 36 to 75 pounds and from 36 to 200 lbs. is presented in table 2.

Initial to 75 Lbs. During this period, the level of protein in the ration significantly affected the rate of gain as measured by the linear and quadratic regressions. The largest increase in daily gain was between the 10 and 12 percent interval of protein (1.06 to 1.26 lbs.). Protein

TABLE 1. ANALYSES OF VARIANCE OF AVERAGE DAILY GAINS AND FEED EFFICIENCIES

Source of Variation	Degrees of Freedom	Mean Squares for Experiment 536				Degrees of Freedom	Mean Squares for Experiment 554			
		36–75 Lb.		36–200 Lb.			31–75 Lb.		31–200 Lb.	
		Daily Gain	Feed/100 Lb. Gain	Daily Gain	Feed/100 Lb. Gain		Daily Gain	Feed/100 Lb. Gain	Daily Gain	Feed/100 Lb. Gain
Replication	1	.....	....	.....	....	2	.....	.....	.....	....
Antibiotic	2	0.0603[1]	1448	0.0054	1306	1	0.0278	272	0.0734[1]	2534[1]
Nil vs. antibiotics	1	0.0729[1]	2750	0.0084	1830					
Aureo. vs. terra.	1	0.0477[1]	145	0.0024	782					
Protein Level	5	0.0971[1]	2023	0.0373[1]	788	5	0.3879[1]	12786[1]	0.1721[1]	2991[1]
Linear component	1	0.2746[1]	4	0.0442[1]	77	1	1.5708[1]	51948[1]	0.2816[1]	2364[1]
Quadratic component	1	0.1495[1]	64	0.1054[1]	1565	1	0.3322[1]	11305[1]	0.4852[1]	9232[1]
Remainder	3	0.0205	3347	0.0122	766	3	0.0128	226	0.0313	1119
Antibiotic x protein level	10	0.0121	1646	0.0066	650	5	0.0006	861	0.0044	157
Experimental error	17	0.0099	1812	0.0093	560	22	0.0180	728	0.0089	418
Total	35	.....	....	.....	....	35	.....	.....	.....	....

[1] Mean squares significant at P=0.05 or less.

levels higher than 14 percent did not produce further increases in gain. The response to level of protein was not significantly influenced by the presence or absence of either of the antibiotics during this period. However, the antibiotic-fed pigs gained on the average significantly faster than those fed no antibiotic (1.34 vs. 1.24 lbs.). Most of this

TABLE 2. EXPERIMENT 536. SUMMARY OF AVERAGE DAILY GAINS AND FEED PER 100 LB. GAIN

(Winter 1951–52)

Antibiotic Per Pound Ration	Protein Levels (%)						Average
	10	12	14	16	18	20	
				Average daily gain (lb.)			
36 to 75 Pounds[1]							
None	1.03	1.11	1.37	1.33	1.34	1.26	1.24
5 mg. aureomycin	1.01	1.36	1.33	1.41	1.29	1.34	1.29
5 mg. terramycin	1.15	1.32	1.52	1.33	1.42	1.54	1.38[2]
Average	1.06	1.26	1.41	1.35	1.35	1.38[3, 4]	
				Feed per 100 lb. gain (lb.)			
None	349	314	310	383	343	296	333
5 mg. aureomycin	329	312	309	277	322	321	312
5 mg. terramycin	300	326	266	346	365	295	316
Average	326	317	295	335	343	304	
				Average daily gain (lb.)			
36 to 200 Pounds[1]							
None	1.44	1.56	1.60	1.64	1.68	1.62	1.59
5 mg. aureomycin	1.44	1.63	1.74	1.70	1.60	1.60	1.62
5 mg. terramycin	1.52	1.68	1.77	1.56	1.66	1.62	1.64
Average	1.47	1.62	1.70	1.63	1.65	1.61[3, 4]	
				Feed per 100 lb. gain (lb.)			
None	390	355	421	370	383	386	384
5 mg. aureomycin	393	361	339	350	376	360	363
5 mg. terramycin	392	363	356	375	382	329	366
Average	392	360	372	365	380	358	

[1] Individual treatment values are averages of 8 pigs (2 pens of 4 pigs each).
[2] Average effect of antibiotic significant at P=0.05 or less.
[3] Linear effect of protein level significant at P=0.05 or less.
[4] Quadratic effect of protein level significant at P=0.05 or less.

increase was due to terramycin. In fact, the average daily gain for pigs receiving terramycin was significantly greater than the average for aureomycin (1.38 vs. 1.29 lbs.). Neither level of protein nor the inclusion of antibiotics had a significant influence on feed efficiency during this period.

Initial to 200 Lbs. During the entire feeding period (36 to 200 lbs.), the level of protein had a significant influence on rate of gain based on the average for all lots of pigs fed each protein level. The

maximum rate of gain was obtained at 18 percent protein without antibiotic but at 14 percent protein with either aureomycin or terramycin. However, there was no significant interaction in rate of gain between the antibiotics and the different protein levels. Even though good experimental practices were followed in obtaining feed requirement figures, it is evident from table 2 that they fail to reveal any definite trend as related to protein level.

The significantly faster daily gains made by pigs fed antibiotics during the earlier period were not evident by the time of termination of the experiment. Although the pigs fed aureomycin or terramycin required 21 and 18 pounds less feed per 100 lbs. gain respectively, these differences were not statistically significant.

Of the 144 pigs starting the experiment, 12 were removed because of a dermatitis condition which could not be related to protein level or the presence or absence of either antibiotic. No excessive looseness of feces was observed at any time during the experiment.

Experiment 554

The average daily gains and feed efficiences are summarized in table 3.

Initial to 75 Lbs. During the 31- to 75-lb. period, the protein level significantly influenced both rate of gain and feed efficiency. As the level of protein was increased, the rate of gain and feed efficiency improved up to 16 percent protein then remained almost constant for higher levels of protein. The influence of protein level on pig performance was quite similar with or without aureomycin. Aureomycin feeding did not significantly improve either rate of gain or feed efficiency.

Initial to 200 Lbs. Over the entire feeding period (31 to 200 lbs.), the protein level significantly influenced both rate of gain and feed efficiency similar to that in the early part of the feeding period. The addition of aureomycin significantly influenced the rate of gain (1.59 vs. 1.68 lbs.) and the feed requirement (354 vs. 337 lbs.). Maximum gains were reached at 16 percent protein without aureomycin and at 14 percent protein with aureomycin. Gains then tended to decrease with higher levels of protein. Therefore, it appears that the feeding of an antibiotic may exert a "sparing-like" effect, possibly indirectly, on the protein requirements of growing-finishing swine.

It might be pointed out that over the entire feeding period, barrows gained significantly faster than gilts (1.68 vs. 1.59 lbs.).

This experiment in terms of pig gains and health, and statistical efficiency, was the best of the series of experiments conducted at the Iowa Station on protein level research. Only one pig out of the total of 144 failed to gain satisfactorily and he was removed from the experiment. As in the previous experiments, no excessive looseness or diarrhea was observed in the pigs on any of the rations.

TABLE 3. EXPERIMENT 554. SUMMARY OF AVERAGE DAILY GAINS AND FEED PER 100 LB. GAIN

(Summer 1952)

Antibiotic Per Pound Ration	Protein Levels (%)							Sex	
	10	12	14	16	18	20	Av.	Barrows	Gilts
				Average daily gain (lb.)					
31 to 75 Pounds [1]									
None	0.84	1.07	1.28	1.48	1.42	1.44	1.26	1.26	1.25
5 mg. aureomycin	0.89	1.11	1.37	1.52	1.49	1.50	1.31	1.31	1.31
Average	0.87	1.09	1.32	1.50	1.46	1.47 [3, 4]	...	1.29	1.28
				Feed per 100 lb. gain (lb.)					
None	323	282	262	234	234	212	258	....	....
5 mg. aureomycin	363	290	235	229	226	237	263	....	....
Average	343	286	248	232	230	224 [3, 4]	...	....	....
				Average daily gain (lb.)					
31 to 200 Pounds [1]									
None	1.25	1.61	1.66	1.75	1.67	1.62	1.59 [2]	1.64	1.54
5 mg. aureomycin	1.35	1.76	1.80	1.76	1.75	1.67	1.68	1.72	1.64
Average	1.30	1.69	1.73	1.76	1.71	1.64 [3, 4]	...	1.68	1.59 [5]
				Feed per 100 lb. gain (lb.)					
None	405	340	336	336	352	353	354 [2]	....	....
5 mg. aureomycin	372	319	329	327	329	344	337	....	....
Average	388	330	332	331	341	349 [3, 4]	...	....	....

[1] Individual treatment values are averages for 12 pigs (3 pens of 4 pigs each).
[2] Average effect of antibiotic significant at $P = 0.05$ or less.
[3] Linear effect of protein level significant at $P = 0.05$ or less.
[4] Quadratic effect of protein level significant at $P = 0.05$ or less.
[5] Average effect of sex significant at $P = 0.05$ or less.

Discussion

Although some inconsistencies exist when comparing the results of the two experiments, overall there is good agreement. Maximum growth rate on the fortified corn-soybean oil meal ration was attained between 16 and 18 percent protein without antibiotic supplementation, and at 14 percent protein with antibiotic supplementation. Further addition of protein above these levels failed to improve gains or feed efficiency. These results are in agreement with those reported earlier by Catron *et al.* (1952).

An effort to discover a statistically significant interaction in gains or feed efficiency between protein level and antibiotic inclusion in the ration was without avail. Otherwise, the relative pig responses on the different protein levels were similar, within limits of experimental error, regardless of whether or not an antibiotic was included in the ration. One cannot ignore, however, the agreement between the two experiments in that pig performance was as good on lower levels of protein with antibiotic as on higher protein levels without antibiotic supplementation. This is in agreement with the results reported by the several investigators previously cited.

Although the feeding of adequate levels of antibiotics of choice appears to have a "protein-sparing" effect, the following criteria would have to be met before this can be established as a fact:

1. Pigs would have to show a greater response to antibiotic feeding at lower than at higher protein levels. There is some, but insufficient, evidence of this to date.

2. There would have to be a statistical interaction between protein levels and antibiotics if the latter actually affect the responses to protein levels. Analysis of the data accumulated to date at the Iowa Station fails to show such an interaction.

3. Antibiotic feeding would have to improve nitrogen retention at any protein level, especially at low levels. Research at the Illinois Station (Brown *et al.*, 1952) failed to show improved nitrogen retention in pigs fed an antibiotic in iso-protein diets.

Perhaps this so-called "protein-sparing" effect of antibiotics is mediated through the multiple mode-of-action which has not been completely elucidated. Evidence to date indicates that antibiotic activity is confined to modifying the intestinal flora, thereby (1) permitting the synthesis of and/or sparing critical nutrients (some of which may affect protein utilization) needed by the host (nutritional effect) and/or (2) inhibiting pathogenic, semi-pathogenic and/or toxin forming microorganisms injurious to the host (disease control effect).

That aureomycin failed to significantly increase early growth rate in either experiment, but terramycin did in the first experiment, cannot be explained on the basis of present knowledge. However, aureomycin did significantly increase daily gains and feed efficiency throughout the entire period for the last experiment. Research to date shows that the greatest response to antibiotic feeding usually is shown in the early growth period.

Since the variation of the two experiments, as measured by the experi-

mental error mean squares, could not be shown to be significantly different, the data (basal and aureomycin-fed groups) for daily gain and feed efficiency have been combined and presented in table 4. A graphic portrayal of the gains and feed requirements for the different protein levels with and without aureomycin for the entire feeding period for both experiments is presented in figure 1.

TABLE 4. EXPERIMENTS 536 AND 554. COMBINED SUMMARY OF AVERAGE DAILY GAINS AND FEED PER 100 LB. GAIN

Antibiotic Per Pound Ration	Protein Levels (%)						
	10	12	14	16	18	20	Average
	Average daily gain (lb.)						
Initial to 75 Pounds							
None	0.91 [1]	1.08	1.32	1.42	1.38	1.37	1.25
5 mg. aureomycin	0.94 [1]	1.01	1.35	1.47	1.41	1.43	1.27
Average	0.93 [2]	1.04	1.33	1.45	1.40	1.40	1.26
	Feed per 100 lb. gain (lb.)						
Initial to 75 Pounds							
None	333 [1]	295	281	294	278	246	288
5 mg. aureomycin	349 [1]	299	265	248	264	271	283
Average	341 [2]	297	273	271	271	258	286
	Average daily gain (lb.)						
Initial to 200 Pounds							
None	1.33 [3]	1.59	1.64	1.71	1.67	1.62	1.59
5 mg. aureomycin	1.39 [3]	1.71	1.77	1.73	1.69	1.64	1.65
Average	1.36 [4]	1.65	1.70	1.72	1.68	1.63	1.62
	Feed per 100 lb. gain (lb.)						
Initial to 200 Pounds							
None	399 [3]	346	370	350	364	366	366
5 mg. aureomycin	380 [3]	336	333	336	348	350	347
Average	390 [4]	341	352	343	356	358	357

[1] Averages of 5 pens of 4 pigs each for each level of protein; standard error for each average is 0.054 lb. for daily gain and 15.5 lb. for feed per 100 lb. gain.
[2] Averages of 10 pens of 4 pigs each for each level of protein; standard error for each average is 0.038 lb. for daily gain and 11.0 lb. for feed per 100 lb. gain.
[3] Averages of 5 pens of 4 pigs each for each level of protein; standard error for each average is 0.043 lb. for daily gain and 9.8 lb. for feed per 100 lb. gain.
[4] Averages of 10 pens of 4 pigs each for each level of protein; standard error for each average is 0.030 lb. for daily gain and 6.9 lb. for feed per 100 lb. gain.

Summary

Protein levels of 10, 12, 14, 16, 18 and 20 percent, with and without 5 mg. of aureomycin or terramycin per lb. of ration, were fed in two experiments (numbers 536 and 554) to a total of 288 pigs. The fortified corn-soybean oil meal rations were fed in concrete drylot to pigs weighing from 31 to 36 lbs. to 200 lbs.

The level of protein in the ration significantly affected the rate of

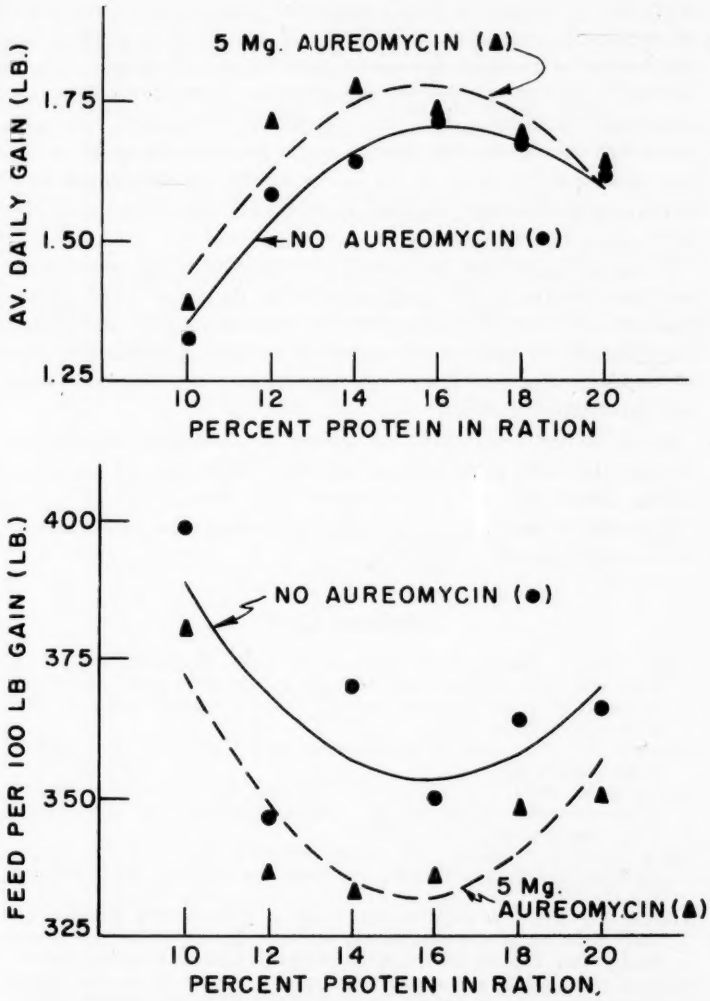

Figure 1. Graphic summary of combined data of experiments 536 and 554 for daily gain and feed per 100 pounds of gain. (Smoothed curves are second degree polynomials).

gain made by the pigs in both experiments as measured by the linear and quadratic components. In general, the average daily gains of the pigs reached a maximum between 16 and 18 percent protein without antibiotics and at 14 percent protein with antibiotics (effect not statistically significant) and then leveled off or declined. Feed efficiency was not significantly affected by the level of protein fed in the first experiment. However, in the second experiment, the protein level had a significant effect on feed requirements which paralleled the performance in daily gains.

In the first experiment, terramycin (but not aureomycin) significantly increased the rate of gain of the pigs during the 36- to 75-lb. period. However, this effect had disappeared by the time the pigs reached 200 lbs. Although the pigs fed aureomycin or terramycin required 21 and 18 lbs. less feed per 100 lbs. of gain respectively, these differences were not statistically significant.

In the second experiment, the feeding of aureomycin significantly increased the daily gains and feed efficiency of the pigs for the entire feeding period, but not for the 31- to 75-lb. period.

The effect of protein levels and antibiotic feeding on carcass measurements will be reported separately.

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DIFFERENT PROTEIN LEVELS WITH AND WITHOUT ANTIBIOTICS FOR GROWING-FINISHING SWINE: EFFECT ON CARCASS LEANNESS [1, 2, 3]

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THE beneficial effects of antibiotics on growth rate and feed efficiency in swine rations have been widely demonstrated during the past few years. However, some concern has been expressed, and some experiments have indicated, that the feeding of antibiotics to swine has resulted in fatter, less desirable carcasses.

Vestal (1950) reported that hogs fed APF (aureomycin and vitamin B_{12}) on alfalfa pasture had 10 percent thicker backfat than those not fed APF. Later, (1951) he reported that the feeding of a B_{12}-antibiotic supplement to pigs up to 125 pounds in weight increased the thickness of backfat slightly when pigs were slaughtered at 224 lbs. in weight, and that backfat thickness increased greatly when the supplement was fed over the entire period.

Bowland and McElroy (1951) stated that it was doubtful whether vitamin B_{12} had any effect on carcass quality, but that aureomycin lowered Advance Registry carcass scores 15 to 23 percent. A year later they (1952) reported that aureomycin or penicillin lowered carcass quality when fed throughout the finishing period, but that there was no adverse effect on carcasses when antibiotic feeding was stopped at 75 or 125 lbs.

These results are not in harmony with those obtained by Terrill *et al.* (1951) who found no significant differences in thickness of backfat or other carcass measurements when 10 to 40 mg. streptomycin per lb.

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[2] This work was partially supported by grants from Lederle Laboratories Division, Pearl River, New York, and Chas. Pfizer and Co., Brooklyn, New York. The vitamins and antibiotics were also supplied by them.

[3] The terms aureomycin and terramycin are used to refer to chlortetracycline and oxytetracycline, respectively, throughout this manuscript.

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of ration was fed to pigs from a weight of 75 to 225 lb. in comparison to no antibiotic. Heidebrecht *et al.* (1951) observed no differences between pigs fed 2.5 to 12.5 mg. penicillin per lb. of ration and those not fed the antibiotic.

Robison *et al.* (1952) demonstrated that as the protein in the ration increased from 9.7 to 19.7 percent, the percent of primal cuts and lean cuts increased consistently, and percent fat trimmings and backfat thickness decreased consistently.

Wilson *et al.* (1953) studied pork carcass values of pigs fed rations containing vitamin B_{12} and aureomycin, alone and in combination. They reported that on a ration averaging 18 percent protein, the addition of 20 mcg. of vitamin B_{12} and 20 mg. of aureomycin, alone or in combination, did not significantly increase the percentage of lean cuts, dressing percentage, back fat depth, or length of carcass. Within the medium protein lots an increase in the leanness of the carcasses resulted from all treatments, the combination of aureomycin and B_{12} resulting in as high a percentage of lean cuts as the high protein basal ration. Supplementation of the low protein ration resulted in an increase in the percentage of lean cuts in each of the three lots, the increase being somewhat greater than in the medium protein groups with similar supplements. Fat deposition was not increased when the addition of vitamin B_{12} and aureomycin accelerated gains.

Earlier, USDA workers (1941) had reported that carcasses from hogs fed to 225 lb. on an 18 percent protein ration contained more lean and less fatty tissue than those fed on 13 percent protein rations. Crampton and Ashton (1946) found no difference in carcass quality of bacon type pigs fed on 13 percent protein rations compared to a 15 percent protein ration.

In this paper results are reported for carcass measurements taken on representative pigs selected from Experiments 536 and 554. One purpose of these studies was to determine the effect of antibiotics and different protein levels on carcass fatness. The procedure and results of the feeding experiments are reported by Jensen *et al.* (1955).

Experimental Procedure

Experiment 536

Fortified corn-soybean oil meal rations containing 10, 12, 14, 16, 18, and 20 percent protein were fed to pigs in concrete drylot from 36 to 200 lb. Two of the six lots of four pigs each on each protein level

received 5 mg. aureomycin and two lots received 5 mg. of terramycin per lb. of ration. Labor and facilities permitted the slaughtering of only one pig from each lot except those lots of pigs on 20 percent protein, where none was slaughtered. Since it was desired to keep the gilts for breeding purposes, a barrow was selected at random from each of the 30 lots for slaughter, giving 2 pigs per treatment. One of the two pigs slaughtered from each treatment was a Duroc and one a crossbred Poland China x Landrace x Duroc. They ranged from 195 to 210 lbs. when slaughtered at the College Meat Laboratory.

Immediately before slaughtering a measure of the depth of backfat hereinafter called the "live probe" was taken at four locations on the live hog as described by Hazel and Kline (1952).

After slaughtering, the carcasses were split and placed in the cooler for 24 to 48 hours before cutting and measuring. The measurements taken included (1) specific gravity of the carcass, (2) length of carcass as determined by the distance from the anterior edge of the first rib to the aitch bone with the carcass hanging from the rail, (3) average depth of backfat measured at the first, seventh, last thoracic and last lumbar vertebrae, (4) weight of leaf fat, (5) percent trimmed lean cuts and (6) the area of the cross section of the loin muscle (*longissimus dorsi*) at the last rib as measured by a planimeter from a tracing. The right side only of the carcass was used for all measurements except specific gravity and weight of the leaf fat.

Experiment 554

The rations for this experiment contained aureomycin but were otherwise similar to those used in the first experiment. There were two lots of four crossbred pigs and one lot of four Duroc pigs on each of the six protein levels with and without aureomycin. One barrow and one gilt were randomly selected for slaughtering at approximately 200 lb. liveweight from each lot of pigs.

The 72 carcasses were treated as described for Experiment 536 and measurements were taken of the same criteria.

All carcass measurements for Experiment 536 and 554 were statistically analyzed according to the plan given in table 3.

Results and Discussion

Experiment 536

A summary of the effect of the treatments on the carcass characteristics studied is presented in table 1. The superscripts of the foot-

TABLE 1. SUMMARY OF CARCASS MEASUREMENTS FOR EXPERIMENT 536

(Winter 1951–52)

Antibiotic Treatment	Protein Levels of Rations Fed %					
	10	12	14	16	18	Average[3]
	Carcass Length (in.)					
No antibiotic[1]	27.8	28.7	28.5	29.2	28.7	28.6
Aureo. (5 mg./lb.)[1]	28.6	28.9	28.9	28.9	29.1	28.9
Terra. (5 mg./lb.)	29.1	28.9	29.4	29.5	29.5	29.1
Average[2]	28.5	28.8	28.9	29.2	28.8	
	Live Probe (in.)					
No. antibiotic	1.7	1.4	1.5	1.4	1.5	1.5
Aureo. (5 mg./lb.)	1.5	1.4	1.5	1.5	1.4	1.5
Terra. (5 mg./lb.)	1.5	1.6	1.6	1.5	1.7	1.6
Average	1.5	1.5	1.6	1.4	1.5	
	Backfat Thickness (in.)					
No antibiotic	1.6	1.5	1.6	1.4	1.6	1.6
Aureo. (5 mg./lb.)	1.7	1.4	1.5	1.5	1.4	1.5
Terra. (5 mg./lb.)	1.6	1.6	1.7	1.4	1.6	1.6
Average	1.6	1.5	1.6	1.4	1.5	
	Specific Gravity					
No antibiotic	1.0168	1.0250	1.0244	1.0302	1.0282	1.0249
Aureo. (5 mg./lb.)	1.0201	1.0272	1.0244	1.0294	1.0305	1.0263
Terra. (5 mg./lb.)	1.0246	1.0242	1.0282	1.0368	1.0249	1.0277
Average	1.0205	1.0255	1.0257	1.0321	1.0278[4]	
	Leaf Fat (lb.)					
No antibiotic	4.5	5.0	4.6	4.9	4.3	4.7
Aureo. (5 mg./lb.)	4.4	4.2	4.4	4.3	3.4	4.1
Terra. (5 mg./lb.)	4.8	4.8	3.4	4.2	3.5	4.2
Average	4.6	4.6	4.2	4.5	3.8	
	Percent Lean Cuts (%)					
No antibiotic	57.0	59.0	60.8	58.5	60.5	59.2
Aureo. (5 mg./lb.)	57.8	59.2	60.8	61.2	59.2	59.7
Terra. (5 mg./lb.)	60.0	56.6	57.6	63.0	57.2	58.9
Average	58.3	58.3	59.7	60.9	59.0	
	Area of Loin Muscle (traced) (sq. in.)					
No antibiotic	3.8	4.4	4.3	4.1	4.3	4.2
Aureo. (5 mg./lb.)	3.8	4.0	3.7	3.7	3.2	3.7
Terra. (5 mg./lb.)	4.1	3.6	3.9	4.5	4.1	4.0
Average	3.9	4.0	4.0	4.1	3.9	

[1] Average of values from 2 carcasses.
[2] Average of values from 6 carcasses.
[3] Average of values from 10 carcasses.
[4] Linear effect of protein levels significant at $P = 0.05$ or less.

notes indicate where significant ($P = 0.05$ or less) effects of treatments have occurred.

The over-all picture is one of highly variable responses both with respect to the three antibiotic treatments and the several protein levels. This situation is graphically portrayed in figure 1. Differences between the antibiotic treatments at the several protein levels were found to be non-significant owing to the relatively large variability among the experimental units (error variance large).

The average effects of the antibiotic treatments were not significant in this experiment, which also reflects the inconsistency of responses. The direction and relative magnitude of the average response of the several carcass characters studied to antibiotic feeding is indicated by the histograms of figure 2 on the basis of indices with the basal response taken as 100. The results of this experiment failed to demonstrate that antibiotic feeding had any important effect on carcass characteristics.

Specific gravity of the carcass was the only character studied that was significantly affected by the level of protein in the ration. Any apparent tendencies to a trend in the other criteria were too small to be shown as statistically significant at the $P = 0.05$ level. The values for specific gravity increased progressively in a linear manner, with each increase in percent protein. Since higher values for this criterion are associated with greater proportions of lean, the above condition indicates that as the protein level was raised from 10 to 20 percent in the ration, by increasing the proportion of soybean oil meal to corn, the carcasses contained a significantly greater proportion of lean to fat.

Experiment 554

Table 2 contains a summary of the several carcass measurements taken in Experiment 554. There was a marked increase in the uniformity of responses to the antibiotic treatments at the different protein levels in this trial compared to those in Experiment 536. This is most easily seen by comparing the graphs of figure 1 with those of figure 3, even though in figure 3 smoothed curves have been fitted to the points.

Statistical analysis of the data shows there are no significant interactions of response of antibiotic treatments and protein levels in any of the criteria studied so that one can proceed directly to a consideration of the average effects of protein levels and of the basal and aureomycin rations on carcass measurements, respectively.

Insofar as the average effects of protein levels are concerned, live probe, specific gravity, percent lean cuts and the cross section area

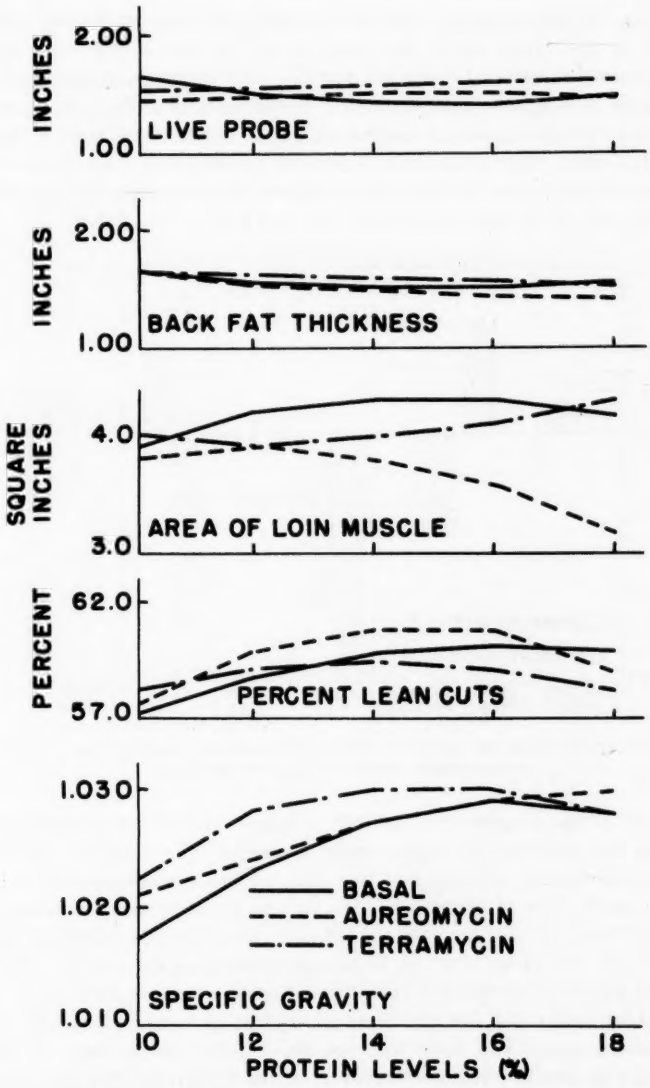

Figure 1. Graphic summary of certain carcass characters for Experiment 536 (Smoothed curves are 2nd degree polynomials).

of the loin muscle show significant responses to changing protein content of the ration. With the exception of the loin muscle area, the measures of carcass fatness are lineraly related to the protein levels (figure 3). This measurement reached a maximum at 18 percent protein (table 2) and decreased somewhat at the 20 percent level. In the case of the other criteria for each increase in protein level from 10 to 20 percent there was a decrease in the values for live probe and backfat depth but an increase for percent lean cuts and specific gravity.

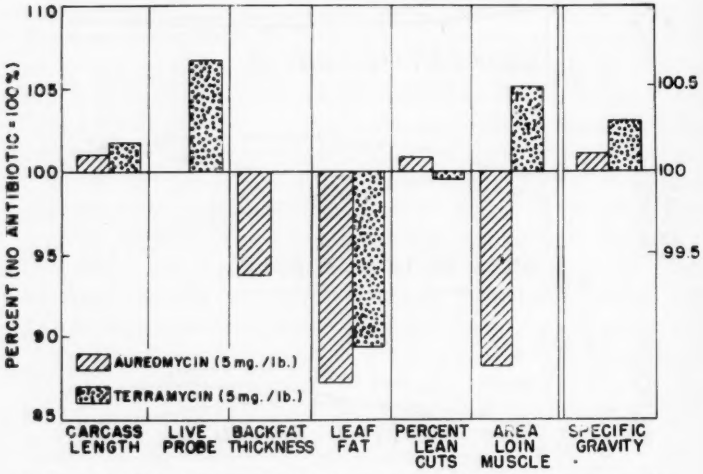

Figure 2. Index bar graph of effects of antibiotic feeding on carcass characters. Basal ration=100 percent.

All of the measurements indicate a leaner type of carcass from the pigs that received the higher levels of protein. The differences in degrees of fatness, between any two adjacent levels would appear to be too small to be of consequence in choosing between such levels as 14 and 16 percent. For example, the estimate (from the best fitting straight line over the range of 10 to 20 percent protein) of the average difference expected between any two adjacent protein levels is 0.054 in., 0.34 percent, and 0.002, for the depth of backfat as measured by the live probe, percent lean cuts, and specific gravity, respectively. If the choice of protein levels were between 10 and 20 percent then the above values would be 5 times as large. The change in these measurements are then of some concern for there might be differences of 0.27 in., 1.70

per cent, and 0.01 in live probe, percent lean cuts, and specific gravity, respectively.

It is surprising that of the characters studied only the cross-section area of the loin muscle appeared to be significantly influenced by the feeding of the antibiotic. Since any increase in the amount of lean in carcasses of a given weight must be accompanied by a decrease in the amount of fat (assuming skeletal weight differences of 200 lb. pigs

TABLE 2. SUMMARY OF CARCASS MEASUREMENTS FOR EXPERIMENT 554

(Summer 1952)

Antibiotic Treatment	Protein Levels of Rations Fed (%)						
	10	12	14	16	18	20	Av.[3]
				Carcass Length (in.)			
No antibiotic [1]	28.4	28.9	28.5	28.6	28.5	28.5	28.6
Aureo. (5 mg./lb.) [1]	28.4	29.0	28.9	28.8	28.4	28.5	28.7
Average [2]	28.4	29.0	28.7	28.7	28.5	28.5	....
				Live Probe (in.)			
No antibiotic	1.5	1.4	1.4	1.5	1.4	1.3	1.4
Aureo. (5 mg./lb.)	1.6	1.6	1.5	1.4	1.4	1.3	1.5
Average	1.6	1.5	1.5	1.4	1.4	1.3 [4]	...
				Backfat Thickness (in.)			
No antibiotic	1.5	1.6	1.6	1.7	1.5	1.5	1.6
Aureo. (5 mg./lb.)	1.6	1.7	1.6	1.5	1.5	1.4	1.6
Average	1.6	1.6	1.6	1.6	1.5	1.5	...
				Specific Gravity			
No antibiotic	1.0203	1.0248	1.0252	1.0250	1.0298	1.0298	1.0258
Aureo. (5 mg./lb.)	1.0162	1.0210	1.0264	1.0257	1.0273	1.0294	1.0243
Average	1.0183	1.0229	1.0258	1.0253	1.0286	1.0296 [4]	.....
				Leaf Fat (lb.)			
No antibiotic	4.1	3.9	4.0	3.9	4.2	4.1	4.0
Aureo. (5 mg./lb.)	3.9	3.8	3.9	3.8	4.0	3.8	3.9
Average	4.0	3.9	4.0	3.8	4.1	4.0	...
				Percent Lean Cuts (%)			
No antibiotic	59.1	59.8	59.4	58.2	60.7	60.9	59.7
Aureo. (5 mg./lb.)	58.6	60.0	60.0	62.2	60.4	61.1	60.4
Average	58.9	59.9	59.7	60.2	60.6	61.0 [4]	....
				Area of Loin Muscle (traced) (sq. in.)			
No antibiotic	3.5	3.4	3.9	3.5	4.1	3.6	3.7
Aureo. (5 mg./lb.)	3.2	3.6	3.6	4.0	3.8	3.6	3.6
Average	3.4	3.5	3.7	3.7	4.0	3.6 [4, 5]	...

[1] Average of values from 3 carcasses.
[2] Average of values from 6 carcasses.
[3] Average of values from 18 carcasses.
[4] Linear effect of protein levels significant at $P = 0.05$ or less.
[5] Quadratic effect of protein levels significant at $P = 0.05$ or less.

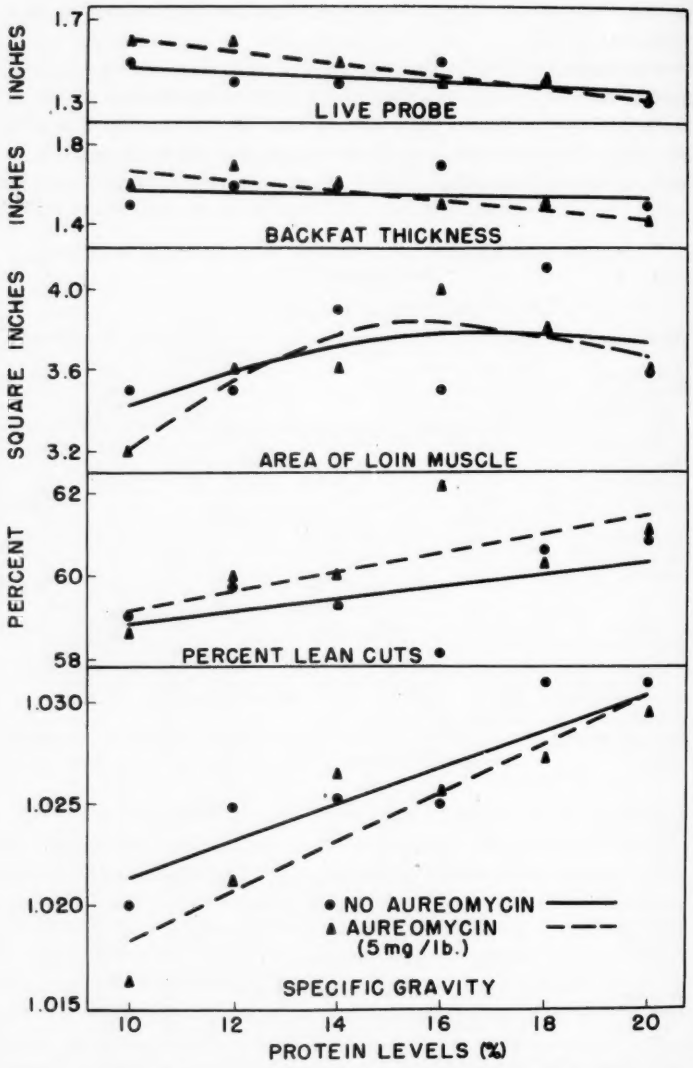

Figure 3. Graphic summary of certain carcass characters for Experiment 554 (smoothed curves are 1st degree polynomials except the 2nd degree polynomial for area of loin muscle).

TABLE 3. ANALYSES OF VARIANCE OF CARCASS DATA

Source of Variation	Degrees of Freedom	Mean Squares: Live Probe	Carcass Length	Specific [1] Gravity	Back Fat Thickness	Area Loin Muscle	Percent Lean Cuts	Weight Leaf Fat
		Experiment 536						
Replication	1	....	....	....	....	....	....	....
Antibiotic(s)	2	0.0324	0.6871	203	0.0187	0.6200	1.535	0.8845
Nil vs. antibiotics	1	0.0038	1.1690	305	0.0008	0.6100	0.104	1.7682
Aureo. vs. terra.	1	0.0610	0.2050	101	0.0367	0.6301	2.964	0.0005
Protein levels	4	0.0129	0.3850	1073	0.0287	0.0475	7.548	0.8176
Linear component	1	0.0015	0.4594	2756 [5]	0.0391	0.0000	9.761	1.9801
Quadratic component	1	0.0055	0.8103	648	0.0118	0.0950	7.322	0.2630
Remainder	2	0.0222	0.2701	444	0.0320	0.0465	6.554	0.5135
Antibiotic x protein levels	8	0.0167	0.2910	185	0.0136	0.1934	7.532	0.1237
Experimental error [2]	13	0.0309	0.3584	367	0.0290	0.4940	14.225	0.6500
Total [3]	28	....	....	....	....	....	....	....
		Experiment 554						
Replication	2	....	....	....	....	....	....	....
Antibiotic(s)	1	0.0130	0.0710	196	0.0018	0.0075	1.480	0.2584
Protein levels	5	0.0408	0.2271	1013 [4]	0.0160	0.2475	3.235	0.0466
Linear component	1	0.1896 [5]	0.0857	4604 [5]	0.0390	0.4388 [5]	14.448 [5]	0.0073
Quadratic component	1	0.0006	0.3125	194	0.0384	0.5462 [6]	0.022	0.0334
Remainder	3	0.0046	0.2460	89	0.0095	0.0850	0.568	0.0642
Antibiotic x protein levels	5	0.0218	0.0440	79	0.0168	0.1638	4.050	0.0036
Experimental error	22	0.0229	0.1606	121	0.0127	0.0752	1.809	0.2167
Total	35	....	....	....	....	....	....	....

[1] Values are mean squares x 10^7.
[2] Degrees of freedom = 12 for Live Probe Area Loin Muscle.
[3] One missing value in all characters of Experiment 536.
[4] Protein level effects significant at P = 0.05 or less.
[5] Linear effects significant at P = 0.05 or less.
[6] Quadratic effects significant at P = 0.05 or less.

to be small), one would expect that carcasses from large muscled pigs would have a higher percent of lean cuts and a thinner depth of backfat than carcasses from small muscled pigs. This relationship is apparent in carcasses from pigs fed aureomycin in the 16 percent protein ration. Larger amounts of lean were associated with increased loin muscle area and a lower depth of backfat. Carcasses from pigs fed terramycin in the 18 percent protein ration had smaller loin muscle areas, lower percent of lean cuts, and more backfat. When aureomycin was fed with the 18 percent protein ration, however, the carcass characteristics did not show this relationship since small loin muscle area and lower percent lean cuts were not associated with increased backfat thickness. Other anomolies in these relationships were observed in the carcasses from pigs on other treatments. The inconsistency of these relationships precludes an explanation concerning the effect of antibiotics on the carcass characters studied.

Summary

Measurements on length of carcass, specific gravity, percent lean cuts, cross-section area of the loin muscle, live probe, depth of backfat, and weight of leaf fat from 102 swine carcasses are reported in this study. The test rations were fed to the pigs throughout the feeding period without alteration of composition.

While there were some discrepancies in the uniformity of response to the imposed experimental treatments in the two experiments in this study, the results are in close agreement. They give no indication that the inclusion of the antibiotics, aureomycin or terramycin, at 5 mg. per lb. of ration in a corn-soybean oil meal ration fed to pigs from weaning to 200 lb. liveweight had an important effect on hog carcass quality.

Feeding pigs protein levels over the range from 10 to 20 percent of the ration resulted in carcasses with a significantly greater proportion of lean as the level of protein increased. This increment in proportion of lean per interval of protein (two units percent) increase is of such small magnitude, however, as to be of minor consideration when a choice must be made between two adjacent protein levels.

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SELECTION FOR FACTORS OF PERFORMANCE IN THE SWINE HERDS OF THE HORMEL FOUNDATION [1]

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IT is recognized that selection, both natural and artificial, has played a large part in the formation of our present breeds of livestock. However, at the present time it appears that certain economically important traits are not responding to selection pressures in the manner expected (Craft, 1951). There is a need for analyses of actual breeding herds to determine whether or not selection is so effective a tool as it appears from the experiments with laboratory animals. This study was undertaken to help provide an answer to this question.

Comstock and Winters (1944) found the actual increases in litter size and average daily gain in inbred lines of Poland China swine to be in reasonably close agreement with the expected increases. Krider *et al.* (1946) reported that 4 generations of selection in Hampshire swine were effective in separating rapidly growing and slowly growing lines. Dickerson and Grimes (1947) were successful in separating lines of swine on the basis of feed requirements by means of selection. Kottman *et al.* (1948), however, found that the levels of performance within 12 inbred lines of Poland China swine were, in general, below those expected with allowance made for the decline due to inbreeding, and for the theoretical improvement due to selection. Dickerson (1951) also reported that selection had produced no improvement in size of litters weaned or in weight per pig at 5 months of age with 49 strains of swine from 5 projects of the Regional Swine Breeding Laboratory. An extensive analysis of the selection practiced in the development of the Minnesota No. 1 and Minnesota No. 2 inbred lines of swine by Fine (1951) indicated that, on the whole, selection was an effective agent in the development of the two lines.

Materials and Methods

The data analyzed in this study were derived from the records of the Chester White and Duroc swine herds operated by the Hormel

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Foundation at Austin, Minnesota. These herds were established in 1944 and 1945 with the objective of the development of superior herds of swine by means of selection. However, severe epidemics of disease brought about a shift in emphasis from breeding to a general attack on the disease problem.

The management of the Hormel herds differs from that in general practice, in that farrowing takes place in every month of the year with no emphasis on any particular season. There has been a continuous attempt to improve the environment of the animals with erection of new facilities and the introduction of improved feeding practices.

Three factors of performance were available for analysis: number of live pigs farrowed, number of pigs weaned, and average weaning weight. Records were available from the Chester White herd on 1,685 litters from 793 different sows for number of pigs farrowed; 1,679 litters from 790 different sows for number of pigs weaned; and 1,437 litters from 676 different sows for weaning weights. In the Duroc herd records were available on 391 litters from 179 different sows for number of pigs farrowed and number of pigs weaned, 335 litters from 165 different sows for weaning weights.

The procedure of analysis was to compare the estimated expected genetic changes with the actual changes. The expected changes were estimated by the product of the selection differential and the coefficient of heritability. The coefficients of heritability used in this study, for the three factors of sow performance, were those presented by Rendel (1950) who listed the coefficients of heritability based on one, two, three and four records as .15, .25, .33, and .38 respectively.

Response to selection was evaluated by means of comparison of the average annual changes with the expected average annual changes. Of course, the annual changes are subject to severe influence by disease, management, nutrition and other environmental factors making actual genetic changes difficult to discern.

Results and Discussion

Selection for Number of Pigs Farrowed

Any attempt to measure the amount of selection practiced for the number of pigs farrowed, or the effectiveness of such selection, is confronted at the outset by the problem of the effect of the age of the dams on the number of pigs farrowed. The fact that older sows farrow more pigs, on the average, than do gilts is well established. As a result

of these age effects, any comparison of the farrowing records among sows can be faulty if due consideration is not given to age differences. An analysis of the Hormel herds demonstrated that the majority of replacements was selected from the litters of older sows.

In order to adjust the farrowing records for the effects of age, correction factors were developed by means of the analysis of multiple covariance (Snedecor, 1946). The data were grouped by months and a regression equation was calculated using the age of the dam as one independent variable, the logarithm of the age as the dam as a second independent variable, and the number of live pigs farrowed as the dependent variable.

The individual regressions indicated that, in the Hormel herds, a maximum litter size in the Chester White herd was reached at about 4½ years, while in the Duroc breed it was reached at approximately 2½ years. However, the fact that fewer older sows were retained in the Duroc herd, makes the figure for this breed less reliable. In fact, a test of significance indicated no significant differences between the regressions for the Duroc and Chester White herds. A regression equation was calculated by pooling the data from the Chester White and Duroc herds. The equation,

$$\bar{Y} = -3.5589 - 0.1078\,x + 11.7739\,w \qquad (1)$$

(where $\bar{Y}$ is the predicted litter size, x the age of the dam in months, and w the logarithm of age of the dam) was used to adjust the records to a common age basis. It was found that the average age at first farrowing was 14 months, therefore all farrowing records were adjusted to that age by means of equation (1).

The management of the Hormel herds differs from the general practice in that farrowing takes place continuously throughout the year. Carmichael and Rice (1920) stated that the litter size had a tendency to be larger in mid-summer and winter than in the spring and fall. Machens (1915) and Johansson (1924) came to the conclusion that there was a tendency for larger litter size in the winter months than in the summer months. A statistical test of the Hormel data indicated that there was no significant difference between the sizes of litters farrowed in different months. This result indicated that no adjustment was necessary for seasonal farrowing.

Selection differentials were calculated for each generation involved. When sows were selected from among the foundation herds to be parents of generation 1, some sows had one record, some had two records,

and some had more. In the calculation of selection differentials, the differences were found between each age-corrected litter record of a sow and the age-corrected average litter size for the year in which her record was made. These differences were summed and averaged. All the records made by a sow up to and including the litter from which the selection was made were included. The differential of each sow was used as many times as the number of females contributed to the next generation. This resulted in groups of sows chosen as parents of generation 1 whose selection differentials were based on one, two, three, and more records. An average selection differential was calculated for each of these groups. Genetic gains expected from selection among the females were estimated by multiplying the average selection differential of each group by the appropriate coefficient of heritability. To arrive at an average expected genetic gain for the generation involved, each group was weighted by the number of differentials going into the group.

The genetic gains expected to result from sire selection were calculated by using their dams' records in the manner outlined for dam selection. Only the records up to and including the litter from which the boar was selected were included. This indirect measurement of selection has the result of at least halving the selection differential attainable from boar selection, based on the records of the dams of the boars (Fine, 1951). The products of one-half the selection differentials by the appropriate coefficients of heritability yield the expected genetic gains. The expected influence of each boar was weighted by the number of his daughters appearing in the next generation.

The expected genetic gain per generation is, of course, the average of the genetic gains expected from sire and dam selection. The expected genetic gain per generation for the Chester White herd was 0.14 pig and for the Duroc herd 0.17 pig. The generation intervals were estimated to be 2.25 years for the Chester White herd and 2.10 years for the Duroc herd. Dividing the average expected genetic gain per generation by these figures resulted in an average expected genetic gain per year of 0.062 pig in the Chester White herd and 0.081 pig in the Duroc herd.

Since the selection differentials were calculated from records converted to a gilt basis and genetic gains are predicted for gilt performance, the yearly average of litter size farrowed by gilts (adjusted to a 14 month of age basis) should reflect changes in genetic merit. The age corrected yearly means of gilt litter size for the Chester White and Duroc herds are shown in table 1. The linear regressions of average

litter size on years were calculated from the data in table 1, each mean being weighted by the number of records which determined it. The average changes per year in litter size were found to be +0.256 for the Chester White herd and +0.302 for the Duroc herd. In both herds the average annual increase in litter size was much larger than was expected through the estimation of expected genetic gains.

The large discrepancy between the expected rate of change per year and the actual rate of change per year indicated that either the method of estimating expected change was extremely inaccurate or the environment played a very strong role. An examination of the environmental or managerial influence appeared essential.

TABLE 1. AVERAGE NUMBER OF LIVE PIGS FARROWED ANNUALLY BY GILTS

(Age-corrected)

	Average Number Farrowed			
Year	Chester White	No. of Litters	Duroc	No. of Litters
1944	8.17	112	7.37	23
1945	7.74	156	7.94	31
1946	7.90	104	6.87	23
1947	8.52	111	9.17	41
1948	8.93	118	9.02	33
1949	9.34	122	8.38	11
1950	8.93	69	7.36	4

The separation of the data into generations offered an opportunity for the examination of a managerial trend. The foundation animals in the Chester White herd were purchased in 1944 and 1945. These O generation females farrowed from one to several litters. Selection from among these several litters resulted in groups of first generation females farrowing their first litters in several different years. Since these first generation females came from different litters of the same group of sows there is no reason to expect that the gilt records of the first generation animals farrowing in any one year should differ markedly from the gilt records of first generation animals farrowing in any other year unless the selection pressure changed. This holds true for any generation considered. With random selection pressure between the groups within a generation, any difference in average litter size should be mainly the result of environmental influence.

Analysis of the data indicated that there was a very definite annual

increase in the average litter size between yearly groups *within the generations*. Inspection of the selection differentials showed that selection pressure within generations was of a random nature and definitely did not follow the same trend as the annual changes. Within each of the first, second, third, and fourth generations a linear regression coefficient was calculated. The mean litter size for each year was weighted by the number of records of which it was composed. The four regression coefficients were then averaged, each weighted by the number of records included. The average coefficient of regression was 0.167. This indicates that of the 0.256 pig average annual increase in the Chester White herd, approximately 0.167 pig increase was due to improvement in environment.

The same type of analysis was carried out for the Duroc herd. The resulting average regression coefficient indicated that of the 0.302 pig annual increase in litter size, approximately 0.239 pig increase was due to improvement in environment.

Selection for Number of Pigs Weaned

The analysis of the effectiveness of selection for number of pigs weaned was made difficult by the severe attacks of "baby pig" disease in the years 1945, 1946, and 1947. This disease, while apparently having only a small effect on the number of pigs farrowed and the average weaning weights, had a great effect on the number of pigs weaned. In the years mentioned, 25, 16, and 15 percent, respectively, of all sows farrowing lost their complete litters. Although the gilts made up less than half of the females farrowing in those years, 60, 82, and 72 percent of the females who lost their litters were gilts.

A detailed analysis of the effect of age on the number of pigs weaned was not possible due to the extreme effects of disease. However, adjustments for age effects were applied by means of the differences between the first and succeeding litters as shown in table 2. All records were adjusted to a first litter basis.

Selection differentials were calculated by comparing the age-adjusted litter records of the litters from which selections were made to the age-adjusted average number of pigs weaned for the year in which the selections were made. The coefficient of heritability of .15 (Rendel, 1950) was used in estimating the expected genetic gains. An expected yearly gain of .14 pig weaned was estimated for both the Chester White and the Duroc herds.

The average annual change in number of pigs weaned by gilts, as

TABLE 2. DIFFERENCES IN NUMBER WEANED WITH SUCCESSIVE LITTERS

Litter	Number of Females	Number Weaned	Average No. Weaned	Diff. between First and Succeeding Litters
1st	965	4768	4.94	....
2nd	555	3458	6.23	1.29
3rd	275	1838	6.68	1.74
4th	141	948	6.72	1.78
5th	69	465	6.74	1.80
6th	35	241	6.89	1.95

measured by the regression of number of pigs weaned in the years 1944, 1948, 1949, and 1950, was estimated at .053 and .197 pig for the Chester White and Duroc herds respectively. Table 3 presents the number of pigs weaned annually by gilts in the two herds.

Due to the complicating nature of the disease problem it was impossible to estimate the within generation change in the number of pigs weaned. Therefore, it was not possible to make any separation of genetic and managerial trends.

Selection for Weaning Weight at 56 Days

Consideration of the average weight of the pigs at weaning encounters once again the effect of the age of the sow. Correction factors, similar to those for number of pigs weaned, were calculated. Table 4, combining data from the Chester White and Duroc herds, presents the average weaning weight per pig for successive litters. The differences between the average weaning weights with successive litters were used to adjust the litter records for sows of different ages to a common age basis. As before, adjustments were made to a gilt basis.

TABLE 3. AVERAGE NUMBER OF PIGS WEANED ANNUALLY BY GILTS

Year	Chester White	No. of Litters	Duroc	No. of Litters
1944	5.75	112	5.36	22
1945	3.56	156	2.90	41
1946	4.14	104	4.48	23
1947	4.01	111	5.51	41
1948	5.80	118	6.42	33
1949	5.96	122	5.55	11
1950	6.18	67	7.25	4

Selection differentials were calculated by determining the difference between the age-adjusted average weaning weights of the litters from which selections were made and the average age-adjusted weaning weight for the year in which the selections were made. The estimates of expected genetic gains in average weaning weights were carried out in the same manner as for the number of pigs weaned. Since only the records of the litters from which selections were made were used in the measurement of the selection differentials, only one figure for the coefficients of heritability, .15 (Rendel, 1950), was used. The average of the selection differential in the females plus one half the selection

TABLE 4. DIFFERENCES IN AVERAGE WEANING WEIGHT WITH SUCCESSIVE LITTERS

Litter	Number of Pigs Weaned	Average Weaning Weight per Pig	Differences between First and Succeeding Litters
1st	4728	21.23 lb.	.....
2nd	3435	24.74 "	3.51 lb.
3rd	1817	25.65 "	4.42 "
4th	940	26.32 "	5.09 "
5th	460	25.74 "	4.51 "
6th	234	24.98 "	3.75 "

differential in the males multiplied by the coefficient of heritability yields the expected genetic gain per generation. Division of this product by the generation interval yields the expected genetic gain per year. Calculations led to an expected gain of .14 lb. per year in the average weaning weight in the Chester White herd and .10 lb. per year in the Duroc herd.

The actual change per year in average weaning weight as measured by the regression of average weaning weight on years, was estimated at +1.01 lb. and +0.30 lb. for the Chester White and Duroc herds, respectively. Table 5 presents the average weaning weight of pigs farrowed by gilts in the two herds.

Estimation of the managerial trend by the method described for the number of pigs farrowed, indicated that of the 1.01 lb. annual increase in average weaning weight in the Chester White herd, approximately 0.80 lb. increase was due to improvement in environment. A similar analysis of the Duroc herd indicated that of the 0.30 lb. increase in average weaning weight, 0.12 lb. was due to improvement in environment.

TABLE. 5. AVERAGE WEANING WEIGHTS OF PIGS FARROWED BY GILTS ANNUALLY

Year	Chester White	No. of Litters	Duroc	No. of Litters
1944	18.62	112	18.97	22
1945	19.42	156	21.08	41
1946	20.57	104	20.33	23
1947	20.66	111	18.28	41
1948	23.37	118	22.11	33
1949	22.41	122	20.48	11
1950	25.57	67	24.02	4

A summary of the genetic gains expected to result from selection and the gains actually attributed to genetic improvement is presented in table 6. The reasonably close agreement between the expected genetic gains and the gains actually attributed to genetic improvement indicates that the method presented in this paper for estimating environmental changes is effective.

As the average litter weaning weight is due more to the suckling ability of the dam than to the genotypes of the individual pigs (Donald, 1939), selection for increased weaning weights must be based largely on the average litter weight. However, Bywaters (1937) estimated that the pigs' own genotypes account for 7 percent of the variation in 56-day weight. Therefore, some attention should be paid to selecting the heavier individuals within litters to obtain the maximum benefits from selection. Analysis of the data indicated that the average of the weaning weights of the selected pigs exceeded the average of all weaning weights by 5.2 lb. in the Chester White herd and 5.5 lb. in the Duroc herd. Since the average weaning weights of the litters from which

TABLE 6. EXPECTED AND ACTUAL CHANGES IN THE THREE MEASURES OF SOW PRODUCTIVITY

Characteristics	Breed	Actual Change	Change attributed to Environment	Expected Genetic Changes	Changes Attributed to Genetic Improvement
Number of live pigs farrowed	CW	.256 pig	.167	.062	.089
	D	.302 pig	.239	.081	.063
Number of pigs weaned	CW	.053 pig	....	.139	....
	D	.197 pig	....	.138	....
Average litter weaning weight	CW	1.006 lb.	.800	.141	.206
	D	.298 lb.	.122	.104	.176

selections were made were 3.3 and 4.9 lb. above the averages of the Chester White and Duroc herds, respectively, it can be seen that the pigs with heavier weaning weights within the litters tended to be the ones selected.

Automatic Selection

Automatic selection is the amount of selection that would occur automatically if the number of pigs selected from each litter were proportional to the number of pigs available in each litter. This is the amount of selection that would occur if pigs were chosen without regard to the size of litters from which they came. A comparison of the actual selection practiced in the Hormel herds and the amount of selection that would have occurred automatically was made in order to gain a general indication of the intensity of selection. This comparison demonstrated that considerable attention must have been paid to selecting pigs from litters that were substantially larger than average both at birth and at weaning, for in every case the actual selection differential was larger than the automatic selection differential.

Summary

Data from the Chester White and Duroc herds operated by the Hormel Foundation at Austin, Minnesota were analyzed to determine how well the selection pressure explained the performance of the herds. Correction factors were developed in order to remove the effect of age of the sows on their performance records for the number of pigs farrowed, the number of pigs weaned, and the average weaning weights of pigs. A consistent and substantial improvement in the management of the herds was demonstrated, and a method was devised to measure this managerial trend in order to proportion properly the improvement due to management and that due to genetic gains.

The effects of disease make the analysis for the number of pigs weaned of little practical value. However, the analysis indicates that selection was effective in bringing about a substantial increase in the number of pigs farrowed and in the average weaning weights. It seems reasonable to expect that with continual rigorous selection much more progress can be expected in the Hormel herds. However, since the traits under consideration have low heritabilities, it is evident that many decades would be required before the ultimate benefits of selection would be realized.

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THE EFFECT OF ARSANILIC ACID AND 3-NITRO-4-HYDROXYPHENYLARSONIC ACID ON SELENIUM POISONING IN THE PIG[1, 2]

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SELENIUM poisoning in pigs has been discussed by Moxon (1937) and Miller and Schoening (1938). The toxic effects of selenium in certain animals can be counteracted by arsenic, as sodium arsenite (Moxon, 1938, 1941; Rhian and Moxon, 1943; Moxon *et al.*, 1944). However, the toxicity of sodium arsenite makes its general use on farms and ranches in seleniferous areas somewhat impractical. Recently Hendrick *et al.* (1953) have shown that both arsanilic acid and 3-nitro-4-hydroxyphenylarsonic acid give partial protection against the toxicity of selenum in the rat, the degree of protection depending upon how much of the arsenical was used. The investigations reported here were made to determine the effectiveness of arsanilic acid and 3-nitro-4-hydroxyphenylarsonic acid as selenium poisoning preventives in pigs.

Experimental Procedure

Experiment 1

Thirty purebred Hampshire, Duroc and Spotted Poland China pigs were allotted to six experimental treatments on the basis of initial weight, breed, litter and sex. All lots were fed and watered *ad libitum* in concrete pens. Weights of pigs were determined at 14-day intervals throughout the experiment. Each pig was removed from the experiment when it weighed 200 lb. or after 112 days on the experiment.

The basal ration was composed of ground yellow corn, solvent soybean oil meal, tankage, steamed bonemeal, trace mineralized salt and a vitamin premix contributing the following per lb. of ration: 6 mg. niacin, 5 mg. pantothenic acid, 1 mg. riboflavin, 125 mg. choline chloride, 4 mcg. vitamin B_{12}, 1000 USP units of vitamin A and 125 USP units of vitamin D. The calculated protein content of the basal

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ration was 15.5 percent. Arsanilic acid was used at a level of 0.01 percent of the total ration and 3-nitro-4-hydroxyphenylarsonic acid at a 0.005 percent level. Selenium was added as sodium selenite to furnish 7 p.p.m. of selenium in the total ration. The arsenical compounds and the selenium were premixed with soybean oil meal and steamed bonemeal before being mixed with the remainder of the ground ration to insure optimum mixing of these compounds in the basal ration.

Experiment 2

The animals used in this trial were purebred Duroc and Spotted Poland China pigs weighing approximately 29 lb. initially. Twenty pigs of each breed were allotted into five outcome groups. Where outcome groups could not be made up of littermates, other comparable pigs were selected. Within the outcome groups, the pigs were assigned to the experimental treatments at random. In order to obtain as little variation as possible in initial weights half of the pigs in each lot were started on the experiment one week prior to the other pigs. The experiment was terminated 14 weeks after the first pigs were started on test.

The basal ration differed from that used in Experiment 1 only in that it contained sodium selenite furnishing 10 p.p.m. of selenium to the total ration. The levels of arsenicals used in this trial were 0.02 and 0.01 percent of the total ration as arsanilic acid and 0.005 and 0.0025 percent where 3-nitro-4-hydroxyphenylarsonic acid was used.

The arsenicals used in these experiments have been reported to prolong blood clotting time in chicks fed rations containing no alfalfa meal or supplemental vitamin K (Griminger *et al.*, 1953; Sweet *et al.*, 1954). Therefore, it was decided to determine if the higher levels of arsenicals used in Experiment 2 had any effect on blood clotting time. Blood was obtained by puncturing the ear vein of each pig in Lots 1, 2 and 4 and the clotting time determined by the capillary tube method.

Results and Discussion

Experiment 1

The results of the first experiment together with the various experimental treatments are shown in table 1. The effectiveness of the two arsenicals used in this study in protecting against selenium toxicity is shown in the growth response of Lot 4 compared to Lots 5 and 6. The average daily gain of Lot 4 is somewhat out of proportion with that of the other groups since the death of the weaker pig raises the final weight

of this group. Three of the five pigs allotted to Lot 4 developed typical selenium toxicity symptoms during the test. Two Duroc pigs showed loss of hair, cracked hoofs and emaciation five weeks after the experiment was started. One of these pigs eventually recovered while the other died at the end of ten weeks. On autopsy this pig exhibited ex-

TABLE 1. RESULTS OF ARSENICAL SUPPLEMENTS IN RATIONS WITH AND WITHOUT SELENIUM FED TO WEANLING PIGS

	Lot Number and Treatment					
	1	2	3	4	5	6
Comparison	Basal	Basal + Arsanilic Acid	Basal + 3-nitro-4 Hydroxy-phenyl-arsonic Acid	Basal + Selenium	Basal + Selenium + Arsanilic Acid	Basal + Selenium + 3-nitro-4 Hydroxy-phenyl-arsonic Acid
Number of pigs	5	4[1]	5	4[2]	4[3]	5
Av. initial wt., lb	30	31	30	32	30	30
Av. final wt., lb.	189	203	198	164	176	201
Av. number of days on test	104	108	102	108	107	104
Av. daily gain, lb.	1.53	1.59	1.64	1.22	1.36	1.64
Av. daily feed per pig, lb.	5.04	5.52	5.33	3.81	4.36	5.36
Av. feed per lb. gain, lb.	3.29	3.48	3.25	3.13	3.20	3.27

[1] Does not include one unthrifty pig removed during the test.
[2] Does not include one pig that died due to selenium poisoning.
[3] Does not include one pig that died due to gastric hemorrhage.

tensive atrophy and cirrhosis of the liver which is typical of selenium poisoning. The other pig that showed the effects of selenium poisoning was a Hampshire. Its hoofs cracked and it became quite lame.

The failure of any of the pigs in Lots 5 and 6 to show any of the above symptoms indicates that the arsenicals were giving some protection. The arsanilic acid at the 0.01 percent level used in this trial did not give complete protection as these pigs gained only 1.36 lb. per

day while those receiving the non-seleniferous diet supplemented with arsanilic acid gained 1.59 lb. per day. Complete protection from selenium poisoning appeared to be given by 3-nitro-4-hydroxyphenylarsonic acid since Lots 3 and 6 had identical rates of gain. The slightly faster rate of gain of the pigs in these two lots is in agreement with the work of Carpenter (1951) who also found 3-nitro-4-hydroxyphenylarsonic acid to stimulate growth in weanling pigs.

TABLE 2. COMPARISON OF DIFFERENT LEVELS OF ARSENICALS IN COUNTERACTING SELENIUM TOXICITY IN WEANLING PIGS

	Lot Number and Treatment				
Comparison	1 Basal	2 Basal +.02% Arsanilic Acid	3 Basal +.01% Arsanilic Acid	4 Basal+.005% 3-nitro-4 Hydroxyphenylarsonic Acid	5 Basal+.0025% 3-nitro-4 Hydroxyphenylarsonic Acid
Number of pigs	8	8	8	8	8
Av. initial wt., lb.	29	29	29	29	29
Av. 10 week wt., lb.	89	129**	116	122*	96
Av. final wt., lb.	152[1]	170	159	167	132
Av. daily gain, lb.	1.28[1]	1.49*	1.37	1.46*	1.09
Av. daily feed per pig, lb.	3.91	5.00	4.50	4.43	3.80
Av. feed per lb. gain, lb.	3.68	3.36	3.28	3.03	3.49

[1] Does not include two pigs removed and autopsied on 84th day.
* Significant at 0.05 level.
** Significant at 0.01 level.

Experiment 2

The second experiment was planned to confirm the results of Experiment 1 and to obtain information on other levels of arsenical supplementation. The weight data for this experiment at 10 weeks, before any of the pigs had died, is included with the summary of the final results presented in table 2.

A significantly greater rate of gain was shown by the pigs receiving either of the arsenicals at the higher levels than by the control lot. This difference was much more pronounced at the end of ten weeks when all of the pigs were still on the experiment. However, even after the two most severely affected pigs had been removed from Lot 1 this lot showed a slower rate of gain than all lots except Lot 5.

Arsanilic acid at the 0.02 percent level and 3-nitro-4-hydroxyphenylarsonic acid at the 0.005 percent level appeared to be equally effective

in counteracting selenium toxicity in this trial. Both of these arsenicals were well tolerated at these levels. Arsanilic acid at the 0.01 percent level was partially effective, the slower rate of gain being due mainly to one pig in that lot that gained poorly during the first few weeks of the experiment. Although several pigs in Lot 5 gained very slowly, 3-nitro-4-hydroxyphenylarsonic acid at the 0.0025 percent level apparently gave some protection since the pigs did not show the visible signs of selenium toxicity as exhibited by two of the pigs in Lot 1.

That a breed difference in susceptibility to selenium poisoning may exist seems likely since in both experiments the Duroc pigs were most

TABLE 3. INFLUENCE OF ARSENICAL SUPPLEMENTS ON BLOOD CLOTTING TIME IN PIGS

Lot No.	Treatment	Av. Blood Clotting Time, Min. and Standard Deviation	
		53rd Day	95th Day
1	None	0.9 ±0.4	2.6 ±0.6
2	0.02% arsanilic acid	1.6*±0.6	4.1**±1.1
4	0.005% 3-nitro-4-hydroxy-phenylarsonic acid	1.9*±0.9	3.2 ±1.0

* Significant at 0.05 level.
** Significant at 0.01 level.

severely affected and showed the toxic symptoms at an earlier date. In neither experiment did the Spotted Poland China pigs exhibit any of the visible symptoms of selenium toxicity. A great deal of variation also was found in the growth response of individual pigs in the lots receiving selenium or selenium plus the lower levels of arsenicals. Some pigs are apparently more susceptible to selenium toxicity than others.

In both trials efficiency of the gains made by the pigs on the seleniferous rations were affected only slightly by the arsenicals. The main cause of the slower growth seemed to be due to a reduced feed intake. This might be expected in view of the dislike for toxic diets reported by Miller and Schoening (1938).

The effect of the two arsenical supplements on blood clotting time is presented in table 3.

The addition of either arsanilic acid or 3-nitro-4-hydroxyphenylarsonic acid to the ration increased the blood clotting time. However, even the longest blood clotting time (4.1 minutes) does not appear to be long enough to be of any practical significance.

In both trials chemical analyses indicated that the arsenicals may prevent at least a part of the selenium from being deposited in the hair as reported by Moxon (1941). However, the results were variable and more data are needed before any definite conclusions can be made.

Summary

Two experiments involving a total of 70 pigs were conducted to determine the effectiveness of arsanilic acid and 3-nitro-4-hydroxyphenylarsonic acid in counteracting the effects of chronic selenium poisoning in pigs. Excellent protection against up to 10 p.p.m. of selenite selenium was given by these two arsenicals at levels of 0.02 percent and 0.005 percent respectively. Partial protection, as evidenced by reduced mortality or increased growth, was shown at the lower levels used (arsanilic acid 0.01 percent and 3-nitro-4-hydroxyphenylarsonic acid 0.0025 percent).

No toxic effects due to the arsenicals were observed at any time during either experiment. In Experiment 1 a slight growth response was shown by the pigs fed the arsenical supplements in a non-seleniferous ration.

A slight increase in blood clotting time was observed in Experiment 2 by the pigs fed the high levels of arsenicals.

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ANTIBIOTICS AND B-VITAMINS FOR LAMBS

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MANY workers (Carpenter, 1950; Catron *et al.*, 1951; Cunha *et al.*, 1950; Jukes *et al.*, 1950) have shown that aureomycin increases the rate of gain and reduces scours in growing-fattening swine. Others (Rusoff and Davis, 1951; Loosli and Wallace, 1950; Loosli *et al.*, 1951) have increased the rate of gain in young dairy calves and decreased the incidence of scours by feeding 20–28 mg. of aureomycin per lb. of feed.

In 1950, Ferguson fed 10 mg. of aureomycin daily by capsule to suckling beef calves obtaining improved rate of gain and reduced incidence of scours. However, feed containing 2 mg. aureomycin per lb. had no effect upon the rate of gain of 18 fattening yearling beef steers when fed for 150 days (Neumann *et al.*, 1951). Other observations by these authors suggested that aureomycin may adversely affect the organisms that synthesize vitamin B_{12}. Recently, Perry *et al.* (1954) stated that aureomycin increased the rate of gain and efficiency of feed utilization of cattle fed a limited concentrate ration.

Colby *et al.* (1950) fed 100 mg. of aureomycin daily to fattening lambs which caused a loss in appetite and body weight. However, when Cunningham and Wasserman (1951) repeated this experiment, their sheep also went off feed in 2 to 3 days, but gradually returned to full feed so that at the conclusion of their experiment, no difference in daily gain existed between the controls and the treated animals. Jordan (1952) fed aureomycin to fattening lambs at the rate of approximately 2.5 to 5.0 mg. per lb. of feed. Aureomycin at these levels did not cause the animals to go off feed or scour. While the higher levels decreased the rate of gain and feed efficiency, it did reduce death losses caused by enterotoxemia and made it easier to get the lambs on full feed.

More recently Jordan and Bell (1954) and Bridges *et al.* (1953), have also fed aureomycin to lambs. These investigators have found that aureomycin produced a small non-significant increase in daily gain and feed efficiency without deleterious effects.

Since the B-vitamins are synthesized in the rumen by microorgan-

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isms, these organisms may be affected adversely by aureomycin. If this occurred, it might explain the negative or lack of positive results that are usually obtained when aureomycin is fed to animals with fairly well developed rumens. It is also possible that lambs may require a longer period to adapt themselves to antibiotic feeding than the usual fattening period. The purposes of this experiment were to study the effect of graded levels of aureomycin with and without B-vitamins in usual fattening rations of lambs, and to determine if previous antibiotic treatment would affect the response of fattening lambs to aureomycin.

Experimental Procedure

Fifty-six western lambs from irrigated pastures were drenched with phenothiazine, matched according to weight, sex and previous history and allotted at random to seven experimental groups during the fall of 1952. The control groups were hand fed twice daily a basal ration of approximately 50 percent clover hay and 50 percent concentrates. The concentrate mixture contained equal parts of ground wheat and barley and 1 percent salt. In addition to the basal ration the other groups were fed 5, 10 and 20 mg. of aureomycin (Aurofac 2A) per pound of concentrates with and without B-vitamins (Lederle's 2-49C). Since the metabolic requirements of lambs for B-vitamins are not known, the vitamins were supplied in amounts that were several times the requirements for hogs of similar weight. An attempt was made at all times to maintain the lambs on full feed, but during periods when the lambs went off feed the amount of grain fed was reduced accordingly. The lambs were fed for 100 days.

The following fall (1953) sixty-four crossbred lambs were allotted in a similar manner to eight experimental groups. These groups were fed four levels of aureomycin (Aurofac 2A), 0, 5, 10 and 20 mg. per lb. of concentrate with and without B-vitamins (Lederle's 2-49C) for an experimental period of 56 days. The basal ration was pelleted and contained 50 percent alfalfa, 30 percent barley, 10 percent wheat, 9.5 percent oats and 0.5 percent salt. At the end of this period, the lambs were slaughtered and dressing percentages and carcass grades were obtained.

During the spring of 1953 twenty orphan wether lambs approximately 2 to 4 weeks of age were divided into two groups according to weight. Each of these groups was divided at random into two lots. One lot of each weight was fed aureomycin (Aurofac 2A) at the rate of 10

mg./lb. of concentrates. In addition the aureomycin-supplemented lambs were fed 10 mg. of aureomycin (Aurofac 2A) daily in the milk. Each lamb was hand fed 0.6 lb. of milk twice daily for the first 50 days. Alfalfa hay and concentrate mixture I composed of 30 percent soybean oilmeal, 20 percent ground wheat, 20 percent ground barley, 20 percent oats and 1 percent salt, was fed *ad libitum* throughout this part of the experiment. At the end of 157 days, each of the lots was divided once again. One group that had previously received aureomycin was continued on aureomycin while aureomycin feeding was discontinued for a similar group. Aureomycin feeding was initiated for a

TABLE 1. CHEMICAL COMPOSITION OF FEEDS

Experiment	Dry Matter	Cmposition of Dry Matter						
		Crude Protein	Ether Extract	Crude Fiber	NFE	Ash	Ca	P
	%	%	%	%	%	%	%	%
1952 (fattening lambs)								
Clover hay	94.48	11.88	3.11	26.63	50.84	8.29	0.20	0.80
Grain mix	89.52	12.12	1.95	4.02	78.83	3.08	0.44	0.06
1953 (fattening lambs)								
Pellets	90.34	12.34	3.07	20.03	58.61	5.95	0.30	0.75
1953 (orphan lambs)								
Alfalfa hay	92.63	15.08	2.20	31.50	42.04	9.18	2.12	0.16
Concentrate mix I	90.47	24.90	6.79	6.47	54.46	7.38	0.18	0.48
Concentrate mix II	90.61	10.96	3.68	5.42	63.87	6.28	0.06	0.42

third group that had not received an antibiotic previously while a fourth group was continued without aureomycin. These animals were fed alfalfa hay and concentrate mixture II composed of 50 percent barley, 29 percent oats, 20 percent wheat and 1 percent salt for an additional 82 days. The chemical composition of the feeds used are given in table 1.

Results and Discussion

The results of the first year are given in table 2.

The response of all experimental groups was poor during this experiment, which was probably caused by internal parasite infestation. Although no significant differences existed in rate of gain, it was noted that lambs receiving 10 mg. of aureomycin per pound of concentrates gained more rapidly with less feed per pound of gain than any of the

other experimental groups. The B-vitamins appeared to have no effect upon gains during the entire feeding period. However, during the first 4 to 7 weeks the lambs fed the supplementary B-vitamins at the 20 mg. level of aureomycin gained more rapidly than the group without B-vitamins at the same antibiotic level. At the conclusion of the experiment, no difference existed between these two groups.

TABLE 2. THE EFFECT OF GRADED LEVELS OF AUREOMYCIN WITH AND WITHOUT B-VITAMINS FOR FATTENING LAMBS (1952)

		Without B-vitamins			With B-vitamins[3]		
		Mg. Aureomycin/lb. Grain Mix			Mg. Aureomycin/lb. Grain Mix		
Treatments	Control	5	10	20	5	10	20
No. of lambs	8	8	8	8	8	8	8
Average, lb.							
Initial weight	64.0	64.1	64.1	64.0	65.3	63.9	62.9
Final weight	83.3	85.7	87.4	85.4	78.8	90.3	84.3
Daily gain	0.19	0.22	0.23	0.21	0.135	0.26	0.21
Feed consumed daily, lb.							
Hay[1]	1.12	1.21	1.17	1.22	1.18	1.17	1.13
Grain[2]	1.20	1.13	1.23	1.09	0.86	1.28	1.20
Total	2.32	2.34	2.40	2.31	2.04	2.45	2.33
Feed/lb. gain, lb.							
Hay[1]	5.79	5.58	4.99	5.71	8.74	4.43	5.29
Grain[2]	6.20	5.22	5.26	5.09	6.39	4.85	5.86
Total	11.99	10.80	10.25	10.80	15.13	9.28	11.15

[1] Predominantly clover.
[2] Composed of equal portions of wheat and barley and 1% salt.
[3] Added in the form of Lederle's 2–49C to supply the following per lb. of feed: 12.4 mg. riboflavin, 24.7 mg. pantothenic acid, 55.7 mg. niacin, 62.0 mg. choline chloride, 0.4 mg. folic acid.

Since a non-significant trend was noted during the first experiment, the experiment was repeated the following year. The results are given in table 3.

With one exception, the data appear to follow the trend noted in the other experiment. Except for the animals fed the zero level of aureomycin without B-vitamins, the lambs receiving 10 mg. antibiotics per lb. of concentrates gained more rapidly with less feed than the other experimental animals. Consistent with the previous experiment, the differences in rate of gain were not significantly different. Neither antibiotics nor B-vitamins affected the dressing percentages or the carcass grades of these slaughtered lambs.

These data indicate either that antibiotics do not inhibit the action

of the rumen microorganisms that normally synthesize B-vitamins or that the feeds used in this study meet the B-vitamin requirements of fattening lambs. The B-vitamin content of the rations was not determined.

A completely pelleted ration in the second experiment made it easier to get the lambs on feed and at no time throughout the experiment did the lambs go "off feed."

Since 10 mg. aureomycin per lb. of concentrates appeared to give the best results during the first experiment, this level of antibiotic

TABLE 3. THE EFFECT OF GRADED LEVELS OF AUREOMYCIN WITH AND WITHOUT B-VITAMINS FOR FATTENING LAMBS (1953)

Treatments	Without B-vitamins				With B-vitamins[1]			
	Mg. Aureomycin/lb. Concentrates				Mg. Aureomycin/lb. Concentrates			
	0	5	10	20	0	5	10	20
No. of lambs	8	8	8	8	8	8	8	8
Average, lb.								
Initial weight	79.4	79.6	78.3	79.9	80.5	78.7	77.6	76.6
Final weight	103.4	96.4	100.5	95.4	96.2	97.0	99.2	96.9
Daily gain	0.43	0.30	0.39	0.28	0.28	0.33	0.39	0.36
Feed consumed daily, lb.[2]	2.83	2.50	2.78	2.42	2.59	2.50	2.69	2.55
Feed/lb. of gain, lb.	8.7	11.0	9.4	11.5	12.1	10.1	9.2	9.3
Dressing %	47.9	49.3	49.1	47.3	49.1	48.4	47.3	47.5
Carcass grades								
Choice	7	6	5	5	6	7	6	6
Good	1	2	2	3	1	–	1	2
Utility	–	–	1	–	1	1	1	–

[1] Added in the form of Lederle's 2–49C to supply the following per lb. of feed 12.4 mg. riboflavin, 24.7 mg. pantothenic acid, 55.7 mg. niacin, 62.0 mg. choline chloride, 0.4 mg. folic acid.
[2] Pelleted alfalfa 50%, barley 30%, wheat 10%, oats 9.5%, salt 0.5%.

was used with orphan lambs the following spring. The results are given in table 4. The heavier lambs fed aureomycin gained slightly faster than any of the other groups, but the difference between any of the treatments was not statistically significant.

The results of the last part of this experiment are given in table 5. Previous antibiotic treatment had no effect upon the rate of gain of these fattening lambs. When the lambs were slaughtered at the conclusion of the experiment, 14 graded choice, one good and two utility. Previous treatment had no effect on slaughter grade or dressing percentage.

TABLE 4. THE EFFECT OF AUREOMYCIN AND DIFFERENT INITIAL WEIGHT ON GROWING LAMBS (1953)

	Heavy Lambs		Light Lambs	
Treatments	Control	Aureomycin[1]	Control	Aureomycin[1]
No. of lambs	5	5	5	5
Average, lb.				
Initial weight	17.5	17.5	13.8	12.7
Final weight	68.8	74.8	63.8	61.0
Daily gain	0.32	0.36	0.32	0.31
Feed consumed daily, lb.				
Milk[2]	1.2	1.2	1.2	1.2
Hay	1.46	1.13	1.37	1.45
Concentrates	0.97	0.85	0.86	0.92
Feed/lb. gain, lb.				
Milk	1.19	1.06	1.19	1.23
Hay	4.56	3.14	4.28	4.68
Concentrates	3.03	2.36	2.69	2.97
Death losses	1[3]	0	1[4]	1[5]

[1] 10 mg./lb. concentrates plus 10 mg. daily in milk for first 50 days.
[2] Fed for 1st 50 days only.
[3, 4, 5] Cause of death: Enterotoxemia, bloat and general morbidity, respectively.

TABLE 5. THE EFFECT OF PREVIOUS ANTIBIOTIC TREATMENT ON THE RESPONSE OF FATTENING LAMBS TO AUREOMYCIN (1953)

Previous Treatment	Aureomycin[1]		Control	
Present Treatment	Aureomycin[1]	Control	Aureomycin[1]	Control
No. of lambs	5	4	4	4
Average, lb.				
Initial weight	66.7	71.2	65.0	67.5
Final weight	86.0	98.3	88.8	90.2
Daily gain	0.24	0.33	0.29	0.28
Daily feed, lb.				
Alfalfa	1.11	1.27	1.35	1.23
Concentrates	1.53	1.74	1.63	1.54
Total	2.64	3.01	2.98	2.77
Feed/lb. gain, lb.				
Alfalfa	4.62	3.85	4.66	4.39
Concentrates	6.38	5.27	5.62	5.50
Total	11.00	9.12	10.28	9.89
Dressing percentage	49.7	47.7	48.4	48.7

[1] 10 mg./lb. of concentrates.

Summary

Graded levels of aureomycin with and without supplemental B-vitamins were fed to 120 fattening lambs and 20 orphan lambs from 2 to 4 weeks of age to market weight. These treatments did not significantly improve the rate of gain, dressing percentage or carcass grade. No adverse effects were noticed that could be attributed to these treatments.

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THE INFLUENCE OF ORAL ADMINISTRATION OF NON-PROTEIN NITROGEN FEEDING COMPOUNDS UPON BLOOD AMMONIA AND UREA LEVELS IN LAMBS [1, 2, 3]

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THE use or urea as a partial replacement for the protein nitrogen in ruminant rations is now an established practice. Loosli *et al.* (1949) found that all ten essential amino acids were synthesized in the rumen of sheep when urea supplied all the nitrogen of the ration. Thomas *et al.* (1951) and Starks *et al.* (1954) demonstrated that lambs made satisfactory growth when urea supplied over 90 percent of the nitrogen of the ration provided the ration was complete in other known nutrients.

The amount of this non-protein nitrogen compound recommended for general use in ruminant rations is limited to low levels principally because of the possibility of toxicity developing when high levels are fed. This toxicity is believed to be due to rapid liberation in the rumen of the ammonia from the urea with subsequent absorption of ammonia into the portal blood resulting in an ammonia toxicity. Dinning *et al.* (1948) have shown an increase in the portal and systemic blood ammonia following administration of a large single dose of urea to one lamb. Rises in the urea and ammonia of the systemic blood were also noted when steers were given a single dose of 100 gm. or more of urea. Clark *et al.* (1951) in studying acute urea toxicity in lambs suggested that the cause of death was not due to absorbed ammonia but possibly to the production of some toxic product of rumen fermentation.

The purpose of this study was to gain more information regarding the mechanism of urea toxicity and amounts required to produce toxicity. A second purpose was to determine whether other NPN (non-protein-nitrogen) compounds might be less toxic than urea and in this respect superior to urea as nitrogen sources in ruminant rations. The

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compounds tested were urea, ammonium acetate, ammonium formate, ammonium propionate and propionamide with limited observations being made on ammonium succinate, formamide, guanidine carbonate, biuret, casein and glycine.

Methods and Materials

For the initial studies on the first five compounds listed above, 30 wether lambs of fine wool breeding, weighing about 75 lb. each were used. Limited observations were also made with the remaining compounds using 15 crossbred lambs. All lambs were fed a ration consisting of .25 lb. soybean oil meal, .75 lb. cracked shelled corn and all the red clover hay of good quality they would consume. In testing the first five compounds the 30 wether lambs were allotted at random into groups of six lambs each. The 15 crossbred lambs were also allotted to treatment at random.

All compounds tested were administered on an equivalent nitrogen basis, with urea being used as a standard. The compounds were put into solution in about a pint of water and given by stomach tube. Precaution was taken to be sure that the end of the stomach tube was inserted into the rumen. For the initial studies feed was withheld for 18 hours prior to drenching, but water was available at all time. The initial dose level for testing was 15 gm. of urea (or its nitrogen equivalent of the other compounds tested) per 100 lb. of body weight. Clark *et al.* (1951) have shown that as little as 18 gm. of urea in a single dose per 100 lb. of body weight will cause death in lambs. Additional dose levels beyond the first dose were increased by increments of 5 gm. of urea equivalent until at least one-half of the six lambs allotted per compound succumbed to treatment. This was then accepted as the toxic level for the compound. Due to the limited number of animals available it became necessary to drench some individual animals more than one time. In these cases at least 10 days were allowed between drenches.

Preliminary studies were carried out in order to determine the time after administration of the NPN compound that the blood ammonia reached its peak. Four lambs were accordingly drenched with 20 gm. urea equivalent of urea, ammonium formate, ammonium propionate and ammonium acetate. The lambs were bled just prior to drenching and at intervals of 10, 20, 30, 50, and 70 and 180 minutes after drenching. Blood samples were taken from the jugular vein. It was found that blood ammonia values were at a maximum at about 30 minutes

after drenching. As the result all lambs drenched with test compounds were bled just prior to drenching and 30 minutes after drenching unless clinical symptoms of toxicity occurred in which case samples were taken more often. While it is realized that analysis of the systemic blood probably does not accurately measure the ammonia being absorbed through the rumen wall it does appear to give a good estimate which can be employed to advantage for routine determinations. Blood ammonia was determined by a micro-diffusion method (Conway, 1950) and urea by an aeration method (Van Slyke and Cullen, 1914).

Based upon the findings with the first five compounds, limited observations were made on the last six compounds, in regard to their effect upon blood ammonia and urea. Limited data were also collected on therapeutic measures attempted in an effort to prevent or alleviate symptoms of toxicity. Several animals were also drenched with urea after being withheld from feed for varying lengths of time. Blood ammonia and urea levels were thus determined in checking the effect of starvation. All animals that died as a result of the tests were necropsied. All values given for blood ammonia and blood urea are micrograms of NH_3-Nitrogen and milligrams of urea-Nitrogen respectively per 100 ml. of whole blood.

Results

In table 1 are recorded the maximum blood NH_3-N values obtained at the various levels of administration of urea, ammonium propionate, ammonium acetate and ammonium formate. The blood NH_3-N levels at which clinical symptoms of toxicity or death resulted are also indicated in this table. It will be noted that no clinical symptoms of toxicity occurred until the blood NH_3-N level rose to approximately 1000γ per 100 ml. Between this level and 1158γ per 100 ml. the animals exhibited ataxia but recovered with one exception. This lamb received ammonium propionate and the maximum recorded blood NH_3-N value was 1076γ per 100 ml.; however, it showed severe symptoms of toxicity for a period much longer than normally observed and finally died nearly six hours after drenching. All other lambs whose blood NH_3-N levels rose higher than 1158γ per 100 ml. developed symptoms of acute toxicity and subsequently died.

Fatal toxicity was first encountered with a lamb drenched with ammonium propionate at the 25 gm. urea equivalent level. One lamb which received this compound at the 30 gm. and a lamb receiving it at

the 35 gm. level also died, although an additional lamb receiving ammonium propionate at the 40 gm. level did not show any clinical signs of toxicity. In the case of urea, ammonium formate and ammonium acetate, fatal toxicity was encountered at the 40 gm. urea equivalent level. The number of animals succumbing to treatment at this level is shown in table 1. With all the lambs that died due to treatment with these three compounds blood NH_3-N levels rose to at least 2045γ per 100 ml. shortly before death.

TABLE 1. MAXIMUM RECORDED BLOOD NH_3-N VALUES (γ/100 ml.) AT THE INDICATED DOSES OF UREA EQUIVALENT

N Compound	0 gm.[1]	15 gm.[2]	20 gm.	25 gm.	30 gm.	35 gm.	40 gm.
	147	146	139	526	663	441	595
Urea		268	155	425	616	1158[3]	2893[4]
			264				2701[4]
							810
							3585[4]
Ammonium propionate	148	329	179	2519[4]	1012[3]	717	
		288	172	458	2925[4]	1076[4]	684
			364		473	670	
Ammonium formate	138	175	279	704	874	758	3355[4]
		184	272	588	413	1003	2656[4]
			409				806
							3304[4]
Ammonium acetate	132	173	275	525	1146[3]	889	3114[4]
		159	280	692	389	479	2045[4]
			410				2872[4]

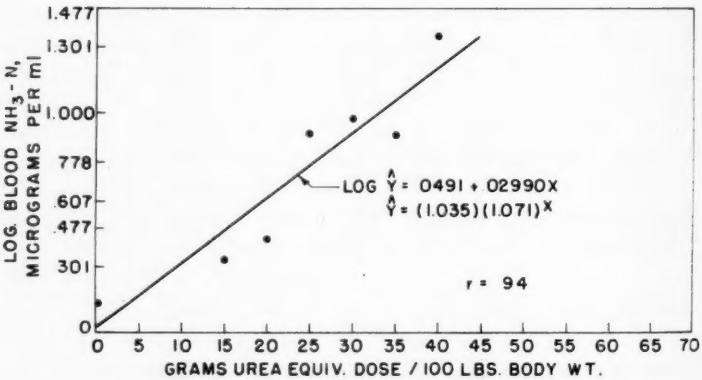
[1] The values for 0 grams are the blood NH_3-N levels prior to drenching and for each compound is an average of the same number of observations given for all test levels of that compound.
[2] Each value given for test levels represents an observation on an individual animal.
[3] Animals exhibited ataxia but recovered.
[4] Animals died.

Figure 1 illustrates the regression of maximum blood NH_3-N values upon dose levels of the toxic compounds. This regression represents 118 individual observations. The values used in this regression are the highest blood NH_3-N values observed at any time following drenching of a lamb with a test compound. The rate of increase in blood NH_3-N values following the administration of toxic doses is presented graphically in figure 2. This graph shows that when lethal doses were administered the blood NH_3-N values rose rapidly. The increase in blood NH_3-N continued until the animals died. When toxic levels of the compounds were administered symptoms of toxicity appeared 30 to 45 minutes after drenching, with death usually occurring 90 to 120 minutes after drenching.

The rise in blood urea-N following administration of lethal doses of the four toxic compounds proceeded at a slower rate than did the ammonia values. This is shown in figure 2a.

Data collected showed that the blood ammonia values of animals which survived treatment with high levels of the toxic compounds started decreasing about 60 minutes after drenching; however, blood urea values were still increasing 80 minutes after drenching. Observa-

FIGURE 1. REGRESSION OF MAXIMUM BLOOD NH_3-N VALUES UPON DOSE LEVELS OF TOXIC COMPOUNDS[1]



1. COMPOUNDS INCLUDED IN THIS REGRESSION ARE UREA, AMMONIUM FORMATE, AMMONIUM ACETATE, AMMONIUM PROPIONATE.

tions on animals surviving after having received toxic and nearly fatal doses of urea, ammonium propionate, ammonium acetate and ammonium formate showed that at 24 hours the blood urea values had not returned to normal.

Extensive observations were also made on propionamide as it was included with the first five compounds tested. However, this compound proved to be non-toxic. Fourteen observations were made with this compound at levels from 15 to 80 gm. urea equivalent. The effect of this compound on blood ammonia and urea is shown in figure 3.

Limited observations were made upon ammonium succinate, formamide, guanidine carbonate, biuret, casein, and glycine. Based upon data collected for the first five compounds these compounds were given initially at or near a urea equivalent dose level that had pre-

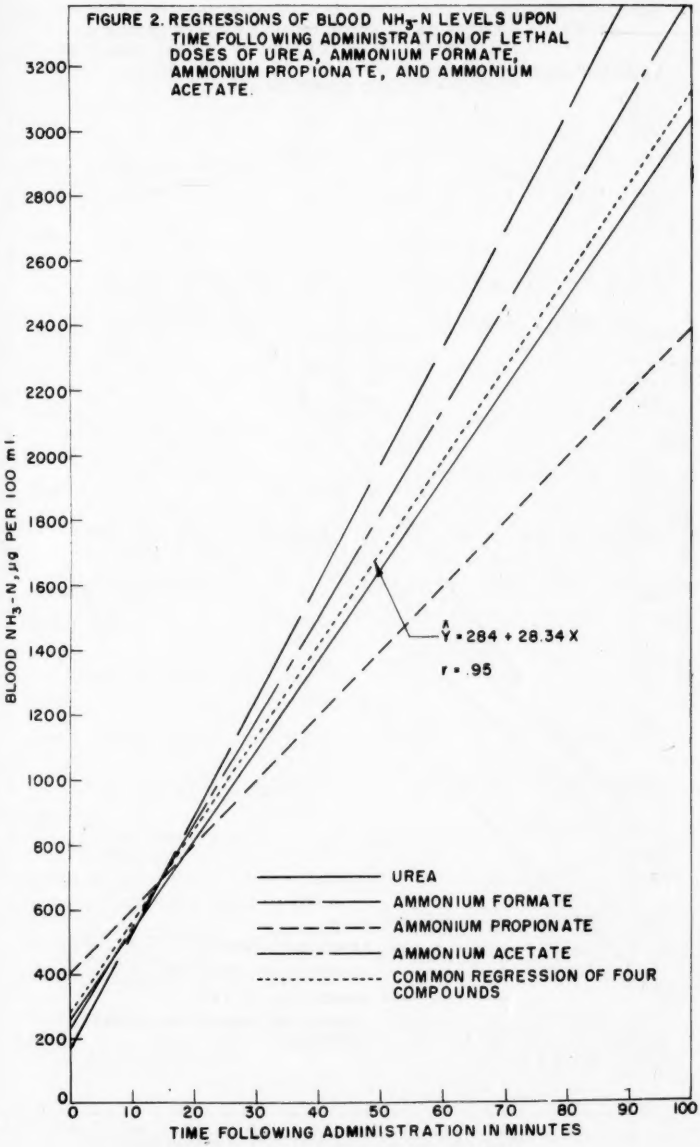


FIGURE 2. REGRESSIONS OF BLOOD NH_3-N LEVELS UPON TIME FOLLOWING ADMINISTRATION OF LETHAL DOSES OF UREA, AMMONIUM FORMATE, AMMONIUM PROPIONATE, AND AMMONIUM ACETATE.
BLOOD NH_3-N, µg PER 100 ml.
TIME FOLLOWING ADMINISTRATION IN MINUTES
Ŷ = 284 + 28.34 X
r = .95
UREA
AMMONIUM FORMATE
AMMONIUM PROPIONATE
AMMONIUM ACETATE
COMMON REGRESSION OF FOUR COMPOUNDS

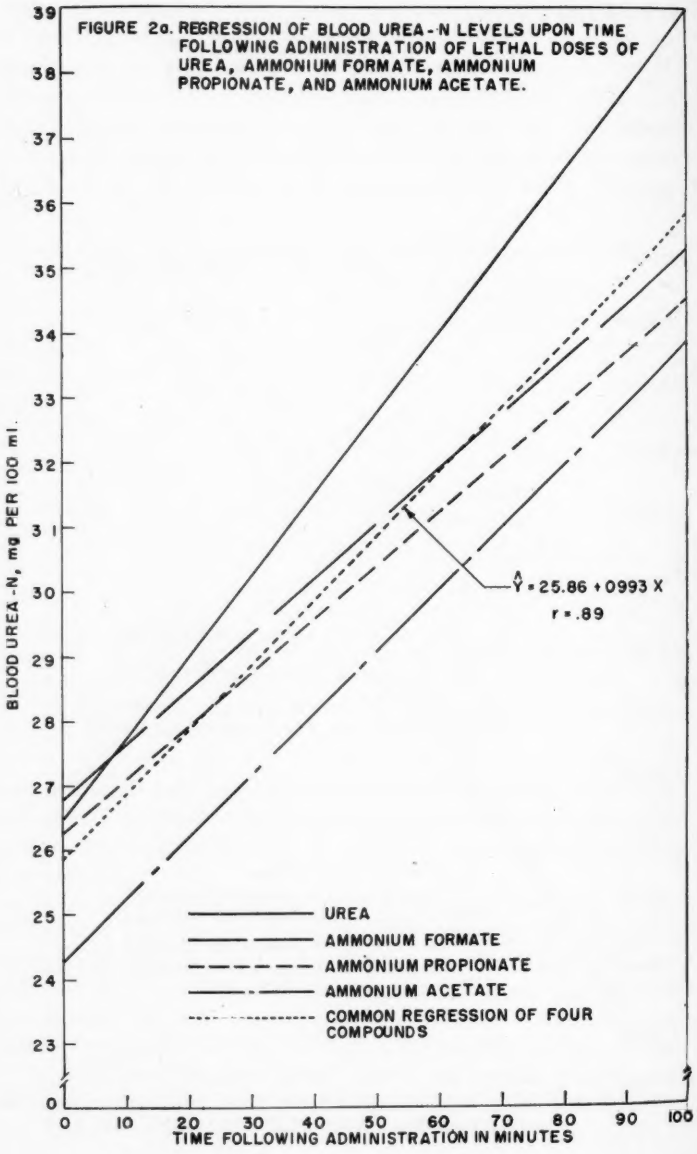
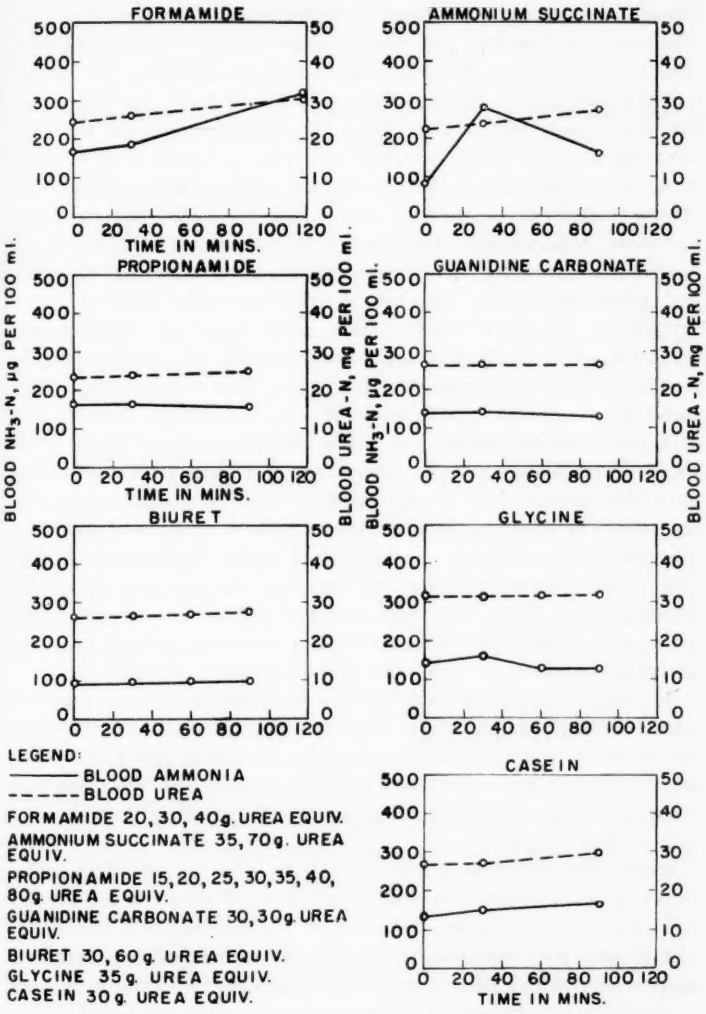


FIGURE 2a. REGRESSION OF BLOOD UREA-N LEVELS UPON TIME FOLLOWING ADMINISTRATION OF LETHAL DOSES OF UREA, AMMONIUM FORMATE, AMMONIUM PROPIONATE, AND AMMONIUM ACETATE.
BLOOD UREA-N, mg PER 100 ml.
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
23
0
0
10
20
30
40
50
60
70
80
90
100
TIME FOLLOWING ADMINISTRATION IN MINUTES
Y = 25.86 + 0993 X
r = .89
UREA
AMMONIUM FORMATE
AMMONIUM PROPIONATE
AMMONIUM ACETATE
COMMON REGRESSION OF FOUR COMPOUNDS

FIGURE 3. OBSERVATIONS ON SUBSTANCES NOT FOUND TO PRODUCE AMMONIA TOXICITY.



viously produced toxicity. In the case of formamide three dose levels were used, two dose levels for guanidine carbonate, ammonium succinate and biuret and with casein and glycine one dose level was used. The results of drenching with these compounds on blood ammonia and urea levels is given in figure 3. The average of dose levels are plotted as there appeared to be little difference due to level. No substantial rise was noted with any of these compounds suggesting that the ammonia was released in the digestive tract very slowly if at all from some of the compounds. In no instance with these compounds did clinical symptoms of toxicity occur. However, with the guanidine carbonate both animals died the night following drenching. Eight hours after drenching these animals had appeared normal. Kutscher and Ackermann (1933) reported on animal guanidine toxicity.

Clark *et al.* (1951) reported that acetic acid when administered intravenously or orally with urea would prevent urea toxicity. In the present study it was found that acetic acid when administered simultaneously as a drench with levels of urea, ammonium formate and ammonium acetate which had previously proven toxic caused distinctly lower blood ammonia values than when the NPN compounds were administered alone. Furthermore no clinical symptoms of toxicity occurred. The effect of the simultaneous dose of acetic acid and toxic nitrogen compounds upon blood ammonia values is shown in figure 4. One normal acetic acid was administered on an equivalent urea ammonia molar basis. One lamb drenched with 80 gm. of acetic acid along with a toxic dose of urea (40 gm.) remained off feed for about 24 hours; however, no symptoms of urea toxicity appeared.

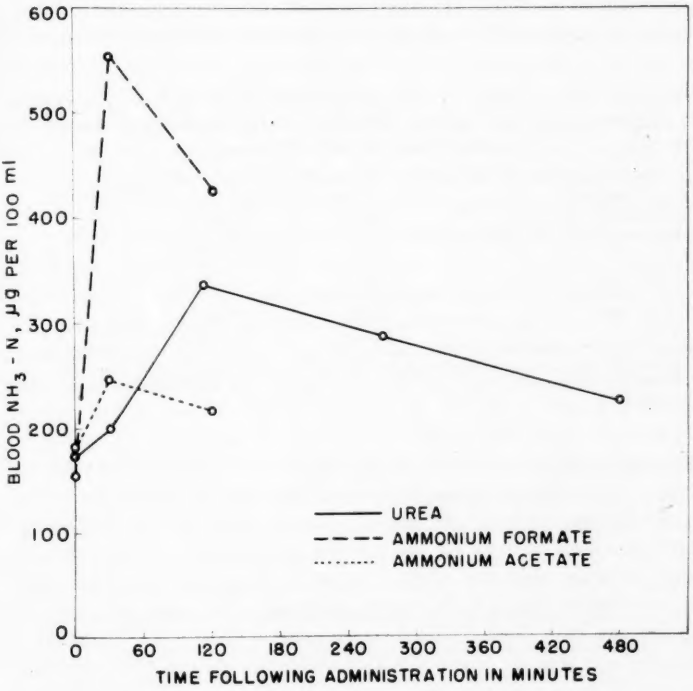
Attempts to alleviate urea toxicity once the symptoms appeared were not completely successful. Administration of acetic acid alleviated symptoms of toxicity in two animals that had been dosed with toxic levels of urea. One animal was exhibiting ataxia and the other had collapsed. However, toxicity could not be reversed if the animals were in a state of tetany.

Intravenous diffusions of 100 and 300 ml. of 1 N acetic acid immediately following drenching with a toxic level of urea did not prevent fatal toxicity. This is in contrast with the findings of Clark *et al.* (1951) who prevented urea toxicity by intravenous administration of acetic acid although they do not state the amounts of acetic acid used.

The effect of dosing with high levels of urea upon animals that had been held off feed for varying lengths of time was also checked. There were two animals per treatment except where fatal toxicity was

encountered. Table 2 shows that withholding feed from 1 to 24 hours did not have any pronounced effect on blood NH_3-N levels. However, there was some suggestion that after a 24-hour fast the high dose levels of urea were somewhat more toxic.

FIGURE 4. BLOOD NH_3-N FOLLOWING SIMULTANEOUS ADMINISTRATION OF NPN COMPOUNDS AND ACETIC ACID.



Discussion

Results presented above show blood ammonia to be a rather critical measurement of the toxicity of NPN compounds. As dose levels of the toxic NPN compounds were increased a rise was noted in blood ammonia. Analysis of the data show a correlation coefficient of 0.94 indicating a high degree of association between blood ammonia values

and the dose level of the toxic compounds. This information suggests that the animals actually succumb to an ammonia toxicity. The most toxic compounds were urea, ammonium formate, ammonium propionate and ammonium acetate. These four compounds were nearly equivalent in toxicity when considered on an equal nitrogen basis with perhaps ammonium propionate being the most toxic of the four. The toxic level of these four compounds when administered as a single drench was about 40 gm. of urea equivalent per 100 lb. of body weight.

The lambs in this study appeared to be able to stand blood NH_3-N values of about 1000 γ per 100 ml. of whole blood without showing

TABLE 2. THE EFFECT OF ADMINISTRATION OF UREA AT VARIOUS TIME INTERVALS AFTER FEEDING UPON MAXIMUM BLOOD AMMONIA VALUES (γ/100 ml.)

Dose Level (gm. urea/100 lbs. wt.)	Time of Administration after Feeding 1 hour	18 Hours	24 Hours
30	154	626	384
35	827	800[1]	1095[2]
40	Fatal Toxicity	Fatal Toxicity	....

[1] Outward symptoms of toxicity in one of two animals represented (animal recovered).
[2] Outward symptoms of toxicity in this animal (acetic acid administered to prevent fatal toxicity.)

outward symptoms. Normal blood NH_3-N levels were between 80 and 250 γ (av. 148). If blood NH_3-N values went no higher than 1150 γ per 100 ml. nearly all the animals survived. Just prior to death blood NH_3-N values of 2 to 3.5 mg. percent were recorded. These observations indicate that the critical range of blood ammonia has rather narrow limits. The NH_3-N values reported in this paper are considerably lower than those reported by Dinning *et al.* (1951). It should be pointed out that the micro-diffusion technique used in this experiment is much more sensitive for blood NH_3-N than the older aeration methods.

When large doses of the toxic NPN compounds were given it was possible to measure an increase in the blood ammonia 15 minutes after dosing. This indicated an extremely rapid liberation of the ammonia from the NPN compounds. The first clinical symptoms appeared at about 30 to 45 minutes after dosing. The animal at this time became

restless and shortly afterward exhibited ataxia. These symptoms were usually of a 10 to 15 minute duration after which the animal collapsed. During this stage of toxicity labored breathing was encountered, accompanied by frothing at the mouth. Bloating sometimes occurred during this period suggesting a cessation of rumen motility. Usually about 25 minutes after collapse the animal went into tetany. Labored breathing continued and bloating was obvious. The skin of the animal took on a blue color which suggested anoxia. Death usually occurred 1½ to 2 hours after dosing. The most consistent findings upon necropsy of animals succumbing to toxic doses of the NPN compounds are as follows: Extensive epicardial and endocardial hemorrhages were nearly always found. The blood vessels were usually cyanotic. A swollen and congested condition was present in most of the kidneys examined. A brownish discoloration of the blood was prevalent in many of the animals suggesting methemoglobin formation. Some hemorrhagic conditions were noted in the abomasum and intestinal tract. The clinical symptoms of toxicity and necropsy findings are similar to those reported by Clark *et al.* (1951).

Several of the compounds tested appeared to be non-toxic in respect to rapid liberation of ammonia. The ammonium salts of the organic acids were toxic with one exception. Ammonium succinate proved to be non-toxic. At present the reason for its low toxicity is unknown. The amides (propionamide, formamide, biuret) were non-toxic. This is presumably due to a lack of amidases in the rumen. Repp (1953) has shown that the nitrogen from propionamide is not readily released in the artificial rumen. Urea which is a diamide of carbonic acid is highly toxic. However, this may be explained on the basis of the high urease activity of the rumen contents which readily liberates the urea ammonia. The amidine guanidine carbonate was not toxic in respect to ammonia toxicity but did cause death of the animals. This is apparently a specific toxicity of guanidine rather than ammonia toxicity. The amine glycine was non-toxic. Belasco (1954) has shown that the nitrogen of glycine is not available to rumen micro-organisms. Hoflund *et al.* (1949) reported that a sheep which had been on a poor diet died following administration of casein. In this study no rise in blood ammonia was noted when casein was administered at a 30 gm. urea equivalent dose level. The nutrition of this lamb was good, although it had been withheld from feed 18 hours prior to drenching.

It is possible that due to their low toxicity some of the compounds may offer promise as nitrogen sources in ruminant rations. However, from feeding tests at this station (Repp, 1953) information has been collected that suggests the more useful NPN feeding compounds are in general the one with the highest degree of ammonia toxicity.

Summary

Ten NPN compounds were administered orally to lambs for purposes of determining their toxicity. These compounds were administered in progressively larger doses and blood samples were taken at varying intervals following administration. Ammonia and urea nitrogen were determined on 350 blood samples taken from thirty lambs in studying the toxicity of urea, ammonium formate, ammonium acetate, ammonium propionate and propionamide. Limited observations were made upon fifteen lambs using ammonium succinate, formamide, guanidine carbonate, biuret and glycine. In all cases except with guanidine carbonate, toxicity was associated with large increases in blood ammonia nitrogen, with the critical level being about 1 mg. per 100 ml. of blood. Administration of urea, ammonium formate, ammonium acetate and ammonium propionate at a level of about 40 gm. urea equivalent resulted in fatal toxicity. Fatal toxicity not associated with an increase in blood ammonia nitrogen was observed after administration of guanidine carbonate at the 30 gm. urea equivalent level. Little if any increase in blood ammonia and urea nitrogen attended the administration of the other compounds. Symptoms of fatal toxicity were alleviated by oral administration of adequate amounts of acetic acid.

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UREA AND METHIONINE IN FATTENING RATIONS FOR LAMBS

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NUMEROUS nitrogen balance trials have confirmed the early results of Harris and Mitchell (1941) showing that urea can be used to supply a part of the nitrogen requirement of lambs for maintenance and growth. Balance trials have further shown that nitrogen retention in lambs fed urea rations is increased by supplemental methionine (Loosli and Harris, 1945; Lofgreen *et al.*, 1947). However, in feed-lot trials urea has not proved to be a satisfactory substitute for protein in rations for fattening lambs (Willman *et al.*, 1946; Pope *et al.*, 1952). The difference in the outcome of results of feed-lot and balance trials has been discussed by Reid (1953) in relation to sulfur and methionine deficiencies in urea rations. In an extensive review covering relevant research Reid (1953) states, "The feasibility of feeding methionine to fattening lambs in the feed lot has not been determined." The purpose of this study was to determine the value of added methionine to a lamb fattening ration.

Experimental

Three lamb-fattening trials with six lots of lambs in each trial were conducted in 1952 and 1953 to determine the value of methionine added to (1) a low-protein basal ration, (2) the basal ration supplemented with urea, and (3) the basal ration supplemented with soybean oil meal. Two trials, Nos. 1 and 3, were conducted in the late summer months, July 10 to October 15, with crossbred Hampshire x fine wool and Suffolk x fine wool lambs from the Experiment Station and commercial flocks. These lambs, which were about 4½ months old, averaged 52 lb. in weight. One trial, No. 2, was conducted in the winter, November 30 to March 6, with fine wool feeder lambs selected from the light end of a group of 350 head. These lambs, which were about 8 months old, averaged 64 lb. In each of the three trials, the lambs were allotted according to weight, sex and breed or source, and the lots assigned to treatment at random. Preceding each trial, the lambs were

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fed adequate rations of alfalfa and prairie hay, oats, and soybean oil meal for a preliminary period of at least 3 weeks. They were drenched with phenothiazine and, in the summer trials, shorn previous to allotment.

During each trial, all lots were allowed prairie hay *ad libitum* and were handfed a basal ration of shelled yellow corn, soybean oil meal, moistened beet pulp and minerals. This ration plus the supplements described below supplied the different lots with equal T.D.N. at a level close to full feed. The supplements fed per lamb daily according to lots were as follows: Lot 1, none; lot 2, two gm. DL-methionine; [2] lot 3, 12.0 gm. urea; [3] lot 4, 12.0 gm. urea plus 2 gm. methionine; lot 5, 0.16 lb. soybean meal; and lot 6, 0.16 lb. soybean meal plus 2 gm. methionine.

The soybean oil meal supplement was added in place of corn in the basal ration. The other supplements were added to the concentrates of the basal ration at feeding time, twice daily. The beet pulp of the basal ration was moistened and allowed to stand for about 12 hours before feeding. Intakes of calcium and phosphorus were equalized with calcium carbonate and bone meal. Salt containing 1 ounce of cobalt chloride per 100 lbs. was available to all lots. Refused prairie hay was weighed daily. The basal ration supplied between 8 and 9 percent protein, and the nitrogen supplemented rations between 10.5 and 12.0 percent.

The initial and final weights of the lambs were obtained after an overnight period without access to feed and water. At the completion of each trial, the lambs were shipped to market (Oklahoma City), and data were obtained on selling price, dressing percentage and carcass grade.

Results and Discussion

The results of each trial are presented separately in table 1. An average result for the three trials is not presented because of the marked difference in response of lambs in trial 2 as compared to trials 1 and 3. As previously mentioned, the lambs in trial 2 represented the light end of a large group of western feeders. Apparently these lambs, as compared to the younger cross-bred lambs of trials 1 and 3, were poor gainers.

[2] The methionine was supplied by the Dow Chemical Company, Midland, Michigan.
[3] The urea was a commercial feed compound ("Two-Sixty-Two") supplied by E. I. DuPont de Nemours and Company, Inc., Wilmington, Delaware.

TABLE 1. RESPONSE OF LAMBS TO SUPPLEMENTAL METHIONINE

Lot No.	1	2	3	4	5	6
	Basal	Basal plus Methionine	Basal plus Urea	Basal plus Urea plus Methionine	Basal plus Soy-bean Meal	Basal plus Soybean Meal plus Methionine
Trial 1. Summer 1952 (90 days, 12 lambs per lot)						
Av. initial wt.	56.3	56.3	56.8	57.2	56.0	56.8
Av. daily gain	.32	.36	.33	.36	.37	.38
Av. daily ration[1]						
Shelled corn lb.	1.43	1.43	1.43	1.43	1.28	1.28
Prairie hay lb.	.88	.89	.89	.88	.95	.95
Dried beet pulp lb.	.17	.17	.17	.17	.17	.17
Soybean meal lb.	.09	.09	.09	.09	.25	.25
Urea gm.	0.0	0.0	12.0	12.0	0.0	0.0
Methionine gm.	0.0	2.0	0.0	2.0	0.0	2.0
Percent crude protein	8.4	8.4	11.1	11.1	10.5	10.5
Calc. lb. T.D.N./cwt. gain	542.0	489.0	533.0	489.0	486.0	474.0
Trial 2. Winter 1952 (96 days, 14 lambs per lot[2])						
Av. initial wt.	64.2	64.2	64.9	63.9	64.1	62.4
Av. daily gain	.19	.19	.20	.21	.27	.24
Av. daily ration[1]						
Shelled corn lb.	1.43	1.40	1.40	1.42	1.31	1.31
Prairie hay lb.	.95	.94	.96	.96	.98	.97
Dried beet pulp lb.	.10	.10	.10	.10	.10	.10
Soybean meal lb.	.09	.09	.09	.09	.25	.25
Urea gm.	0.0	0.0	12.0	12.0	0.0	0.0
Methionine gm.	0.0	2.0	0.0	2.0	0.0	2.0
Percent crude protein	8.4	8.4	11.0	11.0	10.5	10.5
Calc. lb. TDN/cwt. gain	921.0	905.0	865.0	883.0	667.0	750.0
Trial 3. Summer 1953 (100 days, 15 lambs per lot[3])						
Av. initial wt.	48.0	49.6	47.0	48.0	48.3	48.0
Av. daily gain	.37	.36	.37	.40	.42	.44
Av. daily ration[1]						
Shelled corn lb.	1.61	1.61	1.62	1.63	1.49	1.49
Prairie hay lb.	.57	.50	.50	.52	.66	.76
Dried beet pulp lb.	.15	.15	.15	.15	.15	.15
Soybean meal lb.	.09	.09	.09	.09	.25	.25
Urea gm.	0.0	0.0	12.0	12.0	0.0	0.0
Methionine gm.	0.0	2.0	0.0	2.0	0.0	2.0
Percent crude protein	8.9	8.9	12.0	12.0	11.0	10.9
Calc. lb. TDN/cwt. gain	470.0	475.0	470.0	430.0	431.0	423.0

[1] Bonemeal, 4.5 gm. added to rations of lots 1, 2, 3, and 4; $CaCo_3$, 4.5 gm., added to lots 5 and 6; salt (1 oz. of $CoCl_2$/100 lb.) fed, free choice.

[2] Results from one lamb that died in lot 1 werenot included in data

[3] Results from two lambs that died in lot 2 were not included in data.

Addition of approximately 0.18 percent methionine to the basal ration failed to consistently increase average daily gains or feed efficiency of the lambs (lot 2). Likewise, supplementation of the low-protein basal ration with urea to raise the crude protein level to approximately 11 percent failed to improve the overall performance of the lambs (lot 3). It appears that certain factors for efficient utilization of urea as a source of nitrogen by fattening lambs are lacking in a basal ration of this type.

In contrast, the addition of methionine to the urea ration (lot 4) resulted in a small, but consistent, increase in weight gains and feed efficiency in each trial. In no case, however, was this response statistically significant. The trend of results was similar to that reported in nitrogen balance trials (Gallup *et al.*, 1953) in which urea rations but not low-protein rations were improved by methionine. The nitrogen: sulfur ratio of the nitrogen supplements in the urea ration was narrowed from 59:1 (lot 3) to 15:1 (lot 4) by the addition of methionine. This change might well have been a factor contributing to the improved value of the urea ration.

The addition of methionine to the ration supplemented with soybean meal (lot 6) resulted in no consistent difference in response of the lambs. Hence, the beneficial value of methionine in these trials was greatest when a substantial portion of the nitrogen was of non-protein origin.

Lambs fed the basal ration supplemented with soybean meal or soybean meal plus methionine (lots 5 & 6) gained substantially more than those fed the basal ration alone or with the addition of methionine (lots 1 & 2). The increased gain was highly significant (P less than .01) in trial 3 and approached significance in trials 1 and 2. Oil meals have proven superior to urea as nitrogen sources in previous fattening trials (Gallup, Pope and Whitehair, 1953) with lambs. The results of those trials and the present ones would suggest that the poor performance of lambs fed urea as compared to conventional protein supplements was due in part, but not entirely, to lack of methionine (or sulfur). The calculated sulfur content of the basal ration in the present experiment was about 0.1 percent.

The marketing data presented in table 2 show little difference in selling price, dressing percentage or carcass grade among the various lots. The number of carcasses graded as choice was only slightly higher for lambs fed the supplemented rations than for those fed the basal ration alone.

TABLE 2. AVERAGE SELLING PRICE, DRESSING PERCENTAGE, AND CARCASS GRADE

Lot no.	1	2	3	4	5	6
Av. selling price	19.56	19.62	19.32	19.43	19.43	19.70
Av dressing percentage[1]	51.3	50.4	53.0	51.1	50.8	50.0
Av. U. S. carcass grade						
Choice	15	18	22	21	19	18
Good	23	20	16	18	21	21
Utility	2	1	3	2	1	2

[1] Trial 3 only.

Summary

In three feed-lot trials, urea and soybean meal, alone and in combination with methionine, were compared as nitrogen supplements to a low-protein basal ration for fattening lambs. The basal and supplemented rations were similar in T.D.N. and contained about 8.5 and 11 percent protein, respectively.

Methionine and urea added separately to the basal ration failed to improve rate of gain; when added in combination they increased slightly the daily gain in each trial, but the increases were not statistically significant. Soybean meal as a supplement to the basal ration consistently improved rate of gain and feed efficiency. Addition of methionine to the soybean meal ration was without effect.

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THE EFFECT OF PELLETING RATIONS OF VARIED QUALITY ON FEED UTILIZATION BY LAMBS[1, 2]

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In recent years the use of pelleted feeds has increased considerably. Most of the studies to date have been with pelleted feeds for swine and poultry. Neal (1953) reported that the feed required to produce a unit of gain on lambs was reduced when alfalfa was fed as pellets. Noble *et al.* (1953) reported no detrimental effect from pelleting a ration for lambs of 45 percent Redlan Kafir, 50 percent ground alfalfa hay, and 5 percent molasses. Bell *et al.* (1954) reported with lambs greater daily gains on less feed per hundred lb. of gain with a pelleted ration of 45 percent corn and 55 percent hay when compared with the same ration fed as whole corn and long hay. Bell *et al.* (1954) following a six-weeks test reported lambs fed a pelleted creep ration gained faster and more efficiently than similar lambs fed the same ration unpelleted. Jordan *et al.* (1954) in an 86-day trial found that pelleting of good palatable feed such as corn and alfalfa, while it increased its efficiency slightly, was not a profitbale procedure at current prices due to the cost of pelleting.

The study reported here was undertaken to determine the effect of self-fed pelleted and self-fed meal rations of varied quality on the rate and economy of lamb gains.

Experimental Procedure

Approximately ten days prior to starting on feed, 307 lambs weighing about 70 lb. and grading low good in condition were weaned from the Dixon Springs Experiment Station flock. These lambs were fed on alfalfa hay prior to starting on the experimental rations August 28, 1953. The lambs were sired by Suffolk and Hampshire rams and out of western and native black-faced ewes. The lambs were treated for internal parasites with a phenothiazine drench on August 15 and a phenothiazine-lead arsenate drench on August 25. Following drenching,

[1] Approved for publication by Illinois Agricultural Experiment Station.

[2] Feeds were processed by Illinois Farm Supply Company feed mill, Benton, Illinois, through courtesy of Mr. Tom King and Mr. Charles Taylor (plant manager).

lambs were individually weighed, graded, and lotted into six groups. On September 9, approximately one-half of the lambs in each lot were vaccinated subcutaneously with 5 cc of Clostridium perfringens type D bacterin. The lambs were confined to shedded lots throughout the feeding period. Fresh water, salt, and a simple mineral mixture were available to the lambs free-choice.

Individual lamb weights were taken at beginning of test and every 28 days thereafter. On weigh days feed remaining in self-feeders was

TABLE 1. RATIONS

Lot	Self-fed as	Feeds	Feed Proportions		
			1st Week	Next 3 Weeks	Last 8 Weeks
			%	%	%
1	Meal	Alfalfa meal	60	50	40
2	Pellets	Ground yellow shelled corn	40	50	60
3	Meal	Timothy meal	60	50	40
		Ground yellow shelled corn	22.5	34	46.2
		Molasses	5	5	5
4	Pellets	Soybean oil meal	12.5	11	8.8
5	Meal	Timothy meal	60	50	40
6	Pellets	Ground yellow shelled corn	40	50	60

weighed out. During the trial self-feeders were kept well filled and raked down several times each day to insure positive feed. Lambs which graded choice or better were marketed after 56 days of feeding, and all other lambs were sold at the end of 84 days regardless of finish.

The six groups were fed three rations with two lots of lambs on each ration, one of the two being fed on meal and the other on pellets. Rations are given in table 1.

Rations 1 and 2 served as the positive control. Rations 3 and 4 were formulated to equal rations 1 and 2 approximately in total digestible nutrients and in crude protein. Rations 5 and 6 were fed as the negative control. Chemical analyses of the rations for the last 56 days when roughage was 40 percent of the ration are given in table 2.

Results and Discussion

Feeding Results

Lambs in all lots showed little scouring or other digestive troubles. The ratios of roughage to concentrates appeared to be satisfactory in

TABLE 2. AVERAGE ANALYSIS OF SELF-FED RATIONS LAST 56 DAYS OF TRIAL

Rations	Dry Matter	Ether Extract	Ash	Crude Fiber	Crude Protein
	%	%	%	%	%
1 and 2	91.25	3.80	4.94	10.12	13.39
3 and 4	91.37	3.10	4.63	12.14	13.25
5 and 6	91.22	3.18	3.32	14.08	8.35

bringing the lambs onto full feed. However, during the last 28-day-period when roughage was reduced to 40 percent of the ration lambs seemed to crave more roughage and ate some of their bedding.

The pelleted rations were more palatable and were consumed in greater amounts than meal rations except for rations 1 and 2 where daily consumption was nearly equal. Pelleting timothy meal, corn, molasses, and soybean oil meal increased the average daily consumption by 9 percent. Pelleting timothy meal and corn increased average daily consumption by 14 percent. (table 3)

Rapidity of finish was greatest in lots 1 and 2, alfalfa meal and corn ration, where little difference was noticed for pelleting. However, on the other rations, pelleting greatly increased the rapidity of finish

TABLE 3. SUMMARY OF PERFORMANCE[1]

	Lots 1 and 2		Lots 3 and 4		Lots 5 and 6	
	Alfalfa and Corn		Timothy, Corn, Molasses, Soybean Oil Meal		Timothy and Corn	
Ration	Meal	Pellets	Meal	Pellets	Meal	Pellets
Number lambs starting	50	50	52	52	51	52
Deaths	1	2	0	1	1	0
Av. starting weight, lb.	67.9	69.5	68.5	68.1	69.2	67.7
Av. final weight, lb.	94.2	97.0	98.6	103.3	93.2	98.8
Av. starting age, days	189.2	192.0	197.6	193.3	200.7	195.4
Av. days on experiment	65.2	63.5	78.1	70.9	81.8	69.5
Av. daily feed, lb.	2.96	2.89	3.45	3.76	3.08	3.50
Av. daily gain, lb.[2]	.40	.43	.38	.50	.29	.45

[1] Statistical analysis by Professor H. W. Bean.

[2] No difference between lots 1 and 2.
Difference between lots 3 and 4 highly significant (T=7).
Difference between lots 5 and 6 highly significant (T=9).
Difference between all pelleted lots versus meal lots very highly significant (T greater than 10).

TABLE 4. LAMBS MARKETED, 56 DAYS

Meal Lots		Pelleted Lots	
Lot No.	No. Head	Lot No.	No. Head
1	33	2	35
3	11	4	24
5	4	6	27
Total	48	Total	86

to choice grade or better. The first marketings were made at the end of 56 days and the numbers are given in table 4. The balance of the lambs were fed the full 84 days and marketed regardless of finish.

On all rations the amount of feed consumed per hundredweight of gain was less for pellets. Progressively greater economy of feed utilization was realized for pelleting as the quality of the ration decreased. Using the same ration except for physical form, 91 lb. of alfalfa meal and corn pelleted produced the same gain as 100 lb. fed as meal; 84 lb. of the supplemented timothy meal and corn pelleted produced the same gain as 100 lb. fed as meal; and, 74 lb. of pelleted timothy meal and corn produced the same gain as 100 lb. fed as meal. (table 5)

Marketing Data

Each lot of lambs was sold separately at National Stock Yards, Illinois. All lots sold for $20 on a competitive market except lot 5 in

TABLE 5. FEED SUMMARY

	Lots 1 and 2		Lots 3 and 4		Lots 5 and 6	
	Alfalfa and Corn		Timothy, Corn, Molasses, Soybean Oil Meal		Timothy and Corn	
Ration	Meal	Pellets	Meal	Pellets	Meal	Pellets
Feed per cwt. gain, lb.						
Alfalfa meal	329	302	...	...	...	...
Timothy meal	...	...	394	336	459	350
Corn	402	366	370	306	590	431
Soybean oil meal	...	...	86	74	...	...
Molasses	...	...	45	38	...	...
Total	731	668	895	754	1,049	781

which four head sold at the end of 56 days brought $20 and the balance sold later brought only $18. Lot sale weights were obtained; individual carcass weights and grades were taken in the cooler. Table 6 gives market and carcass data.

It will be noted in table 6 that lots 4 and 6, pelleted lots in which timothy served as the roughage, excelled lots 3 and 5, meal lots, in dressing percentage and in carcass grades. The same advantage was not displayed for pelleting where alfalfa served as the roughage.

TABLE 6. MARKETING SUMMARY

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6
Average price per cwt.	$20.00	$20.00	$20.00	$20.00	$18.16	$20.00
Selling weight, lb.	89.4	91.3	92.9	97.5	87.9	92.2
Average carcass, lb.	46.7	47.1	46.0	49.4	43.1	46.7
Dressing percentage	52.23	51.64	49.94	51.97	48.98	50.63
Carcass grades, No.						
Choice	44	42	32	48	25	37
Good	5	6	19	3	20	13
Utility	..	..	..	..	5	2
Cull	..	..	1	..	..	..

Vaccination against Enterotoxemia

Death losses were low being only 5 out of 307. Four losses occurred in the unvaccinated group and one in the vaccinated group. Deaths were diagnosed as due to causes other than enterotoxemia. There was no significant difference in gain of the vaccinated and unvaccinated lambs.

Summary

Three different rations were fed to 307 grade feeder lambs in six lots with two lots of lambs on each ration, one of the two being fed on meal and the other on pellets. The rations were: (a) alfalfa meal and ground yellow shelled corn; (b) timothy meal, ground yellow shelled corn, soybean oil meal, and molasses calculated to be approximately equal in total digestible nutrients and crude protein to the alfalfa meal and ground yellow shelled corn ration; and, (c) timothy meal and ground yellow shelled corn. The following conclusions are drawn:

1. Pelleting significantly increased average daily gains on the two

rations using timothy meal as the roughage; no significant increase was shown for pelleting the ration using alfalfa meal as the roughage.

2. Pelleting increased feed consumption on rations using timothy as the roughage, but not on the ration using alfalfa as the roughage.

3. Feed required per hundred lb. of gain on lambs was lower for all rations fed in pelleted form. The greatest advantage occurred on the lowest quality ration.

4. A greater proportion of lambs fed a ration in pelleted form reached market at 56 days than similar lambs fed the same ration in meal form.

5. Higher carcass grades were obtained with pelleted feeds when timothy was the roughage, but there was little difference when alfalfa was the roughage.

6. Vaccination against enterotoxemia did not affect the rate of gains.

This trial indicated that pelleting alfalfa meal and corn was of slight value, hardly enough to warrant the cost of pelleting. The pelleting of rations containing timothy meal greatly increased economy as well as rate of gain. It is interesting to note that the two lots eating pelleted rations in which timothy was the roughage out-gained the control lots, 1 and 2, receiving alfalfa as a roughage indicating that lambs will make satisfactory gains on low quality roughages in self-fed rations if their daily feed consumption is adequate. The practical aspect of pelleting is the feasibility of using low quality roughages as a part of self-fed lamb fattening rations.

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MODIFIED UREA SUPPLEMENTS WITH CORN SILAGE FOR WINTERING EWE LAMBS [1, 2, 3]

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CORN silage is an excellent roughage for wintering lambs when supplemented with additional calcium, phosphorus, and protein. Harris and Mitchell (1941) showed that lambs fed corn silage *ad libitum* as the sole feed were unable to maintain their weight and were in negative nitrogen balance. The addition of a urea supplement however converted the silage into a ration capable of promoting normal or nearly normal growth. Hamilton *et al.* (1948) and Briggs *et al.* (1948) using metabolism experiments found that urea can satisfactorily replace one-third of the protein in a ration for lambs making fair growth.

Loosli and Harris (1945) found that the addition of methionine to rations containing urea increased nitrogen retention of lambs. Other workers, Hale and Garrigus (1953), Block *et al.* (1951) and Block and Stekol (1950), using labeled inorganic forms of sulfur, (S^{35}), showed that the ruminant can utilize and convert inorganic sulfur into wool and milk proteins. Cornell workers, Loosli *et al.* (1949), showed that the ten essential amino acids were synthesized in large amounts in ruminants fed urea as the only nitrogen source. Starks *et al.* (1953) using the paired feeding technique showed that elemental sulfur could be used by sheep to supply partially their dietary needs of sulfur when added to a urea-containing ration low in sulfur. Thomas *et al.* (1951) found that lambs performed poorly, or in some instances died, when fed a ration low in sulfur. The addition of sulfate salts to the deficient sulfur diets enabled the lambs to make a 0.2 lb. daily gain.

Teeri *et al.* (1953) using fecal and urinary excretion values concluded that while sulfur dioxide destroys much of the thiamine in silage it favors rumen synthesis of thiamine.

[1] Published with the approval of the Illinois Agricultural Experiment Station.

[2] This is the sixth paper in a series on sulfur in sheep nutrition.

[3] We acknowledge with thanks the counsel of Dr. H. W. Norton on the statistical analyses of the data. Urea was generously furnished by the E. I. du Pont de Nemours and Company, Inc., Wilmington, Delaware.

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[5] Department of Animal Science, Urbana, Illinois.

The studies reported here were made to determine the performance of ewe lambs when fed a wintering ration of corn silage with various urea supplements.

Experiment 1, 1951–52

Experimental Procedure

Ninety-two western crossbred ewe lambs averaging approximately 85 lb. were randomly allotted into four groups. The lambs were housed in a 3-sided shed, opening into small lots to the south, and had access to trace mineralized salt (sulfur free) and water at all times. They were lot-fed five lb. of corn silage per lamb daily, divided between a

TABLE 1. DAILY FEED PER LAMB, WINTER, 1951–52

Feed	Lot 1	Lot 2	Lot 3	Lot 4
Corn silage, lb.	5.00	5.00	5.00	5.00
Soybean oil meal, 44% solvent, lb.	.25	.08	.08	.08
Urea, gm.	....	11.81	11.81	23.62
Cerelose, gm.	....	61.74	61.74	61.74
$CaHPO_4$, gm.	3.78	4.28	4.28	4.28
Salt (trace mineralized), gm.	9.08	9.08	9.08	9.08
Sulfur, gm.	....	....	5.00	5.00

morning and night feeding, with the mixed supplements sprinkled over the silage. The rations of the four lots are given in table 1.

The ration of lot 1 is one commonly used at the Illinois Station for wintering ewe lambs. In lot 2 two-thirds of the nitrogen of soybean protein was replaced by urea nitrogen. The ration of lot 3 was comparable to that of lot 2 except for addition of elemental sulfur. Lot 4 lambs were given twice the amount of urea as fed to the lambs of lots 2 or 3 and also received elemental sulfur. Cerelose was added to the urea supplements in order to equalize their total digestible nutrient content with that of soybean oil meal. Supplements were equalized also for total nitrogen, phosphorus, calcium, and salt.

Each lamb was weighed at 28-day intervals. Wool yields were determined by the method used by Starks *et al.* (1953).

Weight gains and wool growth data were treated by covariance analysis (Snedecor, 1946) to remove the effect of differences in food refusals.

Results and Discussion

The average daily gains and wool growth during the winter of 1951–52 are shown graphically in figure 1. At the end of the wintering period

there was little difference in average weight gains in lots 1, 3, and 4. Willman *et al.* (1946) found that lamb gains were similar when urea replaced two-thirds of the nitrogen of linseed meal used as a supplement to a daily ration of approximately 3.5 lb. of corn silage and 1 lb. of corn. Doubling the urea nitrogen in lot 4 did not increase the weight gains of the lambs. While average daily gains of lot 3 were greater than those of lot 2 the advantage was not statistically significant.

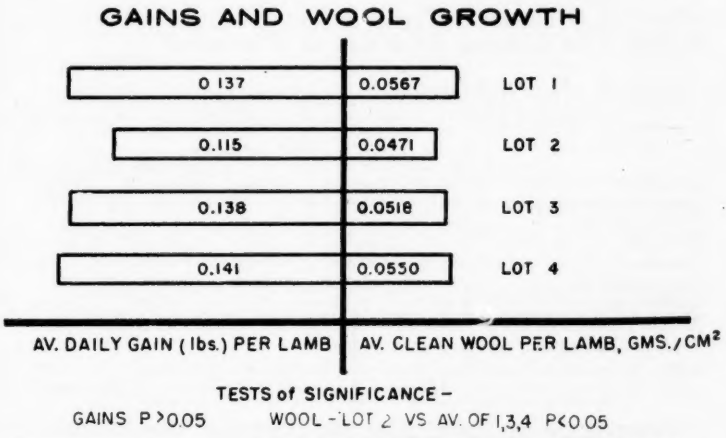

Figure 1. Lamb gains and wool growth during 131-day wintering period, 1951–52.

An analysis of covariance showed a significant difference between the average wool growth of lambs in lots 1, 3, and 4 compared with wool growth of lot 2, but no significant difference among lots 1, 3, and 4.

Feed refusals per lamb during the wintering period were 2.35, 8.85, 3.71, and 13.36 lb. of feed respectively for lots 1, 2, 3, and 4. Thus feed refusals indicate that the lot 3 ration, urea-cerelose-sulfur, was eaten almost as well as the soybean meal supplemented lot. Lot 2 lambs receiving urea and cerelose did not relish their ration as well as the lot 3 lambs which received a similar supplement with sulfur added. It was interesting to note that the refused feed of lot 2 consisted chiefly of the fibrous stalk part of the corn silage. Ray (1953) found that the addition of phosphorus and elemental sulfur to low quality roughage containing urea improved crude fiber digestion by steers.

Experiment 2, 1952–53

Experimental Procedure

In this study 36 crossbred ewe lambs with an initial individual weight of approximately 73 lb. were used. The wintering period consisted of three feeding phases.

During phase 1 all lambs were lot fed for 37 days with each lamb receiving 4.2 lb. of corn silage daily and the group 2 urea supplement as shown in table 2. Phase 1 was used to accustom the lambs to the ration and to provide the basal wool growth data. Each lamb was weighed at the beginning and at the end of the period.

TABLE 2. DAILY SUPPLEMENTS ADDED TO CORN SILAGE, 1952–53

	Daily per Lamb				
Supplement	Group 1	Group 2	Group 3	Group 4	Group 5
Soybean oil meal, lb.	0.25	....	....	....	....
Urea, gm.	....	17.70	17.70	13.94	13.94
Cerelose, gm.	....	45.40	45.40	....	....
Corn starch, gm.	....	45.40	45.40	....	....
$CaHPO_4$, gm.	4.54	7.22	7.22	4.56	4.56
Ground yellow corn, lb.	....	....	....	0.25	0.25
Trace mineralized salt, gm.	9.08	9.08	9.08	9.08	9.08
Sulfur, gm.	....	....	1.6	....	1.6

Following the lot feeding phase the lambs were allotted randomly into five groups. During phase 2 (56 days duration) each lamb was fed twice daily equal amounts of silage and its respective supplement. Supplements as shown in table 2 were formulated to be equal in energy and nitrogen. Soybean oil meal served as the protein supplement for group 1. Urea replaced all of the soybean meal in groups 2 and 3 to which equal parts of cerelose and starch were added as the energy source. Ground yellow corn furnished the energy and 18.5 percent of the nitrogen for the urea supplements of groups 4 and 5. Elemental sulfur was added at the rate of 1.6 grams daily to supplements of groups 3 and 5.

During phase 3 (28 days duration) sulfur dioxide preserved silage was fed all lambs. Each lamb was fed and received the same supplement as in phase 2.

Kjeldahl nitrogen determinations were made on the silages and supplements. All feeds were analyzed for total sulfur by the A.O.A.C. method (1950).

Nitrogen balance of a representative lamb of each of the five groups

was determined during each phase of the study. Collection periods were six days in length after a perliminary cage adjustment period of two days. During the collections of phase 1 and 2 each lamb received 4.4 lb. of corn silage plus supplement, while during the collections of phase 3 each lamb received 5 lb. of corn silage plus supplement.

The same procedure as used during the first winter was used to check wool growth of each lamb during phase 1 and the combined wool growth of individual lambs during phases 2 and 3. In analyzing individual wool yields each lamb's wool growth during phase 1 was used as the standard against which its wool growth during phases 2 and 3 was contrasted.

Lamb gain and wool yield data were analyzed by the method of covariance to remove effects of differences in food refusals.

Results and Discussion

Weight increases made during phases 2 and 3, with statistical tests of significance, are shown in figure 2. Wool data are summarized in table 3; nitrogen balances are shown in figure 3.

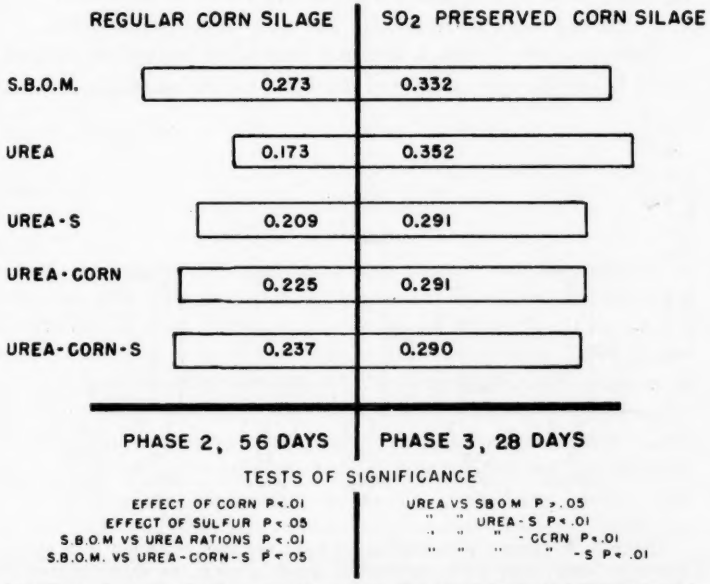

Figure 2. Average daily gains in pounds per lamb during phases 2 and 3 with tests of significance.

TABLE 3. WOOL GROWTH PER LAMB DURING PHASES 2 AND 3, 1952–53

Ration supplement	Grams per Cm^2	
Soybean oil meal	0.0353	
Urea	0.0297	
Urea and sulfur	0.0343	
Urea and corn	0.0311	
Urea and corn and sulfur	0.0360	P about 0.06

The lambs receiving the soybean meal supplement during phase 2 made significantly greater weight increases (P less than .01) than did the lambs receiving the modified urea-containing rations. It is interesting to note that the substitution of corn for the energy sources cerelose and starch affected a highly significant improvement, (P less than .01) in lamb gains. The gains of the lambs receiving the urea plus corn supplement were not, however, as large as the gains made by the soybean oil meal supplemented lambs. All lamb gains in this experiment are regarded as good wintering gains. Willman *et al.* (1946) found that the substitution of urea plus additional corn for all of the linseed meal in a fattening ration of corn silage and corn reduced lamb gains.

Sulfur analyses in table 4 showed a total sulfur percentage of 0.111 and 0.120 in the corn silage on a dry basis fed during phases 1 and 2

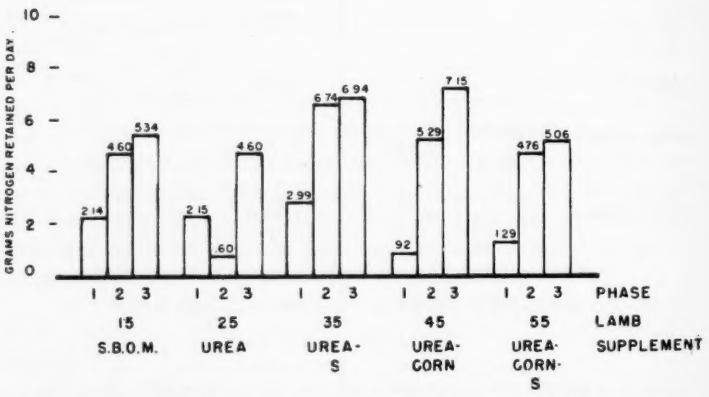

Figure 3. A graphic presentation of daily nitrogen retention of a representative lamb from each supplement group during the three phases of the 1952–53 winter study.

respectively. Thus the sulfur contents of group 2 and group 4 rations during phase 2 were approximately 0.101 and 0.121. The addition of 0.2 percent elemental sulfur to such rations significantly improved lamb gains. Starks *et al.* (1953) found that the addition of 0.2 percent elemental sulfur or the addition of 1.33 percent sodium sulfate to a purified ration with urea as the major nitrogen source and containing 0.054 percent total sulfur significantly increased lamb gains. Jones *et al.*

TABLE 4. CHEMICAL ANALYSES OF FEEDS, PERCENT ON DRY BASIS, WINTER, 1952–53

Lamb groups	I	II	III	IV	V
Supplements	Soybean Oil Meal	Urea-Starch-Cerelose	Urea-Starch-Cerelose-Sulfur	Urea-Corn	Urea-Corn-Sulfur
Percent N.	6.99	7.05	6.96	6.65	6.66
Percent total S.	0.220	0.011	1.28	0.125	1.12

	Regular corn silage		Sulfur dioxide preserved silage
Silages	Phase 1	Phase 2	Phase 3
Percent dry matter	30.13	29.73	30.21
Percent N.	1.22	1.32	1.25
Percent total S.	0.111	0.120	0.259

Calculated total sulfur of ration Supplement plus silage	I	II	III	IV	V
Phase 2	0.137	0.101	0.320	0.121	0.309
Phase 3	0.253	0.220	0.420	0.236	0.406

(1946) found that the addition of one percent sodium sulfate to a wintering ration with less than 0.13 percent total sulfur and with urea serving as a partial nitrogen source improved wintering gains of dairy heifers. Lofgreen *et al.* (1953) were unable to show any improvement in lamb gains from the addition of 0.2 percent inorganic sulfate to a fattening ration in which urea furnished 40 percent of the nitrogen of the ration. The total sulfur content of Lofgreen's fattening ration was 0.2 percent before supplementation. It is possible that the addition of sulfur to a corn silage ration and to less concentrated rations may have a different effect upon rumen flora than the addition of sulfur to a fattening ration without corn silage.

Analyses of the sulfur dioxide preserved silage fed during phase 3

showed 0.259 percent total sulfur on a dry basis. During phase 3 the substitution of sulfur dioxide preserved silage for regular corn silage erased the statistical advantage that soybean meal supplementation affected upon lamb gains during phase 2. It is interesting to note that during phase 3 the gains of groups 2 and 4, the urea supplemented groups without sulfur added, were significantly greater than those of groups 3 and 5 in contrast to a reverse finding during phase 2. It would appear that the sulfur added by the sulfur dioxide silage to hitherto sulfur-low rations was responsible for these improved lamb gains.

Analyses of wool data are based upon the combined growth of individual lambs made during phases 2 and 3. While wool growth differences are not significantly different (P about 0.06), table 3 shows that wool yields seem to follow lamb gains of phase 2. Thus the soybean oil meal supplemented lambs that made the greatest average daily gain in phase 2 also showed the greatest wool yield while the urea supplemented group 2 lambs which showed the smallest daily gains yielded the least wool.

An analysis of average daily nitrogen retention data showed P about 0.06. Nitrogen balance data, figure 3, show that lambs of groups 1, 3, 4, and 5 all retained more nitrogen during phase 2 than during phase 1 while the lamb of group 2 receiving the urea-cerelose-starch supplement retained the least nitrogen. This is in accord with findings of Starks *et al.* (1953), that lambs on low sulfur rations retained less daily nitrogen than lambs receiving a similar ration plus supplemental sulfur. The nitrogen retention of each lamb improved during phase 3. This increased retention may be explained partially on the basis that each lamb was eating 5 lb. of silage during phase 3 collections and only 4.4 lb. silage during phase 2. The large improvement in nitrogen retention from phase 2 to phase 3 may have been due either to a larger intake of silage or to the increased sulfur content in the silage.

Summary

Two wintering studies with western crossbred ewe lambs were made using urea supplements with corn silage. The daily supplements fed contained amounts of nitrogen and energy equal to that in 0.25 lb. of 44 percent soybean oil meal.

Initially in the 1951–52 lot feeding test urea replaced two-thirds of the nitrogen of soybean oil meal. Cerelose was added for energy. Elemental sulfur was included in two supplements at the rate of 5 gm. daily per lamb. Average daily gains per lamb in pounds for 140 days

were: soybean 0.137; urea-cerelose 0.115; urea-cerelose-sulfur 0.138; twice urea plus sulfur 0.141. Gains were not significantly different. Wool yields for the urea-cerelose-sulfur group while greater than for the urea-cerelose group were not significantly different. Average wool yields for soybean oil meal, urea-cerelose-sulfur, and for twice urea groups were statistically greater than for the urea-cerelose treatment.

In 1952–53 urea supplements were formulated without soybean oil meal. One source of energy used was equal parts cerelose and starch and another was yellow corn. This second study included a 37-day lot feeding period (phase 1) of corn silage with a urea-cerelose-starch supplement followed by a 56-day individual feeding period (phase 2) of regular corn silage and modified urea supplements. SO_2 treated corn silage was fed the last 28 days (phase 3). During phase 2 the soybean oil meal supplemented lambs made highly significantly greater gains than lambs receiving modified urea rations. The addition of 0.2 percent elemental sulfur to modified urea supplements increased gains significantly, and the use of ground corn as an energy source in place of cerelose and starch affected a highly significant improvement in gains. Nitrogen balances improved through the addition of sulfur and from the use of corn but differences were not significant. Wool growth favored the sulfur supplemented rations, though not significantly.

Upon feeding of sulfur dioxide preserved silage during the last 28 days statistical differences in lamb gains of phase 2 were erased.

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EFFECT OF MINERAL SUPPLEMENTS ON DIGESTIBILITY OF A CORNCOB RATION BY SHEEP[1]

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Oklahoma Agricultural Experiment Station[3]

IT has been demonstrated that the addition of alfalfa ash will improve the digestibility of rations containing corncobs as the principal roughage by steers (Burroughs, Gerlaugh and Bethke, 1950) and by sheep (Swift *et al.*, 1951). Scott (1951) at the Oklahoma station noted that alfalfa ash supplementation improved the reproductive and lactation performance of ewes fed prairie hay, corn and corn gluten meal. Further studies have been made to confirm these observations and to attempt to determine which of the constituents of alfalfa ash are responsible for the improvement.

Experimental

Twenty uniform, crossbred wether lambs averaging 75 lb. were selected for this experiment. They were treated with a phenothiazine preparation two weeks prior to the start of the experiment. The lambs were randomly divided into four lots of five lambs each. Each lamb was fed its respective ration in an individual stanchion; when not stanchioned, each lot was allowed the freedom of a large box stall, without bedding. Feces were collected by means of a light harness and bag similar to that described by Garrigus and Rusk (1939). Daily fecal collections were weighed and aliquot samples taken for analysis. The samples were kept in tightly sealed jars and were refrigerated at about 4° C until analyzed. Further details of the digestion trial procedure are given by Gallup *et al.* (1950).

The proximate composition of the ration components and of the basal ration is given in table 1. All lambs were fed a basal corncob ration having the following percentage composition: Ground corncobs, 45; ground yellow corn, 25; corn gluten meal, 20; corn syrup, 7; corn oil, 3. Each lamb also received daily a supplement of dicalcium phos-

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phate, 7 gm., iodized salt, 5 gm., cobalt sulfate, 0.2 mg., and cod liver oil, 1 gm. The basal ration and supplement, which together are designated as ration 1, supplied a maintainance allowance of total digestible nutrients and was adequate in protein, calcium, phosphorus, and cobalt. It was characterized by a very low total ash content, 1.6 percent. Animals receiving this ration without additional supplementation are designated Lot 1; all other lots were fed on an iso-caloric basis, receiving 700 gm. of basal ration per lamb per day, which provided 628 gm. of organic matter. A second group of lambs (Lot 2) were each fed in addition 14 gm. of a mineral mixture composed of NaCl, 900 grams;

TABLE 1. PERCENTAGE COMPOSITION OF FEEDS AND BASAL RATION FED TO LAMBS

(Dry Matter Basis)

Feeds	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	N-Free Extract	Ash
Corn cobs	93.8	3.4	1.5	36.1	57.4	1.6
Corn	88.6	9.7	1.8	2.0	85.1	1.4
Corn gluten meal	91.2	40.2	1.5	4.3	51.3	2.7
Corn syrup	77.5	0	0	0	97.7	0.3
Corn oil	0	0	100.0	0	0	0
Basal ration	90.6	12.5	4.7	18.0	63.2	1.6

$M_gSO_4 \cdot 7H_2O$, 300; KCl, 200; $CuSO_4$, 3.5; $MnSO_4 \cdot 6H_2O$, 1.0; $ZnCl_2$, 1.0; $FeSO_4 \cdot 7H_2O$, 1.5. This mineral mixture was formulated to meet, together with the supplement, the common mineral requirements for sheep as recommended by the National Research Council (Pearson *et al.*, 1949). A third group (Lot 3) were each fed 35 gm. of alfalfa ash, prepared by burning a high-grade alfalfa hay in an open tank, followed by complete incineration in a muffle furnace at 500° C. A fourth group (Lot 4) were each fed 43 gm. of a "synthetic alfalfa ash" composed of purified salts simulating the mineral composition of dehydrated alfalfa as reported by Schrenk and Silker (1950), and others. It contained: $KHCO_3$, 2350 grams; K_2HPO_4, 850; $CaCl_2$, 550; $Ca(OH)_2$, 1100; $M_gSO_4 \cdot 7H_2O$, 1600; $FeSO_4 \cdot 7H_2O$, 225; $NaHCO_3$, 700; $Na_2B_4O_7 \cdot 10H_20$, 100; $MnSO_4 \cdot 4H_2O$, 10; $CuSO_4 \cdot 5H_2O$, 70; $ZnCO_3$, 6.

The lambs were fed their respective rations for an 8-day preliminary period. This was followed by eight successive 3-day collection periods (Trial A). This technique was used because in preliminary experiments (Chappel, 1952) there appeared to be an effect of time in attainment

of maximum effect from alfalfa ash supplementation. It was hoped that frequent short-time collections would reveal any progressive effect and would also provide information on the variability of different collection periods. Following the eight 3-day collection periods, a single reversal technique was used in which the ration previously fed to Lot 1 was fed to Lot 3 and the ration previously fed to Lot 2 was fed to Lot 4. Following a second 8-day preliminary period, three successive 3-day collections were made (Trial B).

Results and Discussion

The average apparent digestion coefficients of ration components by lambs fed the various mineral supplements are given in table 2. The average of the eight successive 3-day trials in each lot is reported under Trial A. The average of the three 3-day single-reversal trials is reported in trial B. The data for Trial A were analyzed statistically by the method of variance, and the pertinent mean squares are presented in table 3. Statistical analysis for Trial B is not given, but the data is presented because of the similar trends observed.

The addition of a mixture of the common minerals to the basal ration (which contained supplemental salt, iodine and cobalt) had no influence on the condition or behavior of the animals. There was no improvement in the apparent digestibility of any of the fractions studied.

The addition of either alfalfa ash or a "synthetic alfalfa ash" compounded of purified salts significantly increased the apparent digestibility of the organic matter and crude fiber fractions of the ration. Other fractions were also digested to a greater extent, though differences were not in all instances statistically significant.

Comparison of the effects of the natural ash of alfalfa with the mixture of purified salts simulating alfalfa ash indicated that the natural product gave slightly better results insofar as digestibility of the ration components was concerned. However, these differences were not statistically significant, absolute differences between the two treatments amounting to only a percentage difference of 1.2 in organic matter as compared with a difference of 6.0 percent between the basal ration and the one supplemented with alfalfa ash.

The effective component(s) of the ash on the mixture of salts has not been determined. In these experiments, unlike those reported by Bentley and Moxon (1952) with steers, all rations were supplemented with cobalt in adequate amounts. It does not appear likely, therefore,

TABLE 2. APPARENT DIGESTION COEFFICIENTS OF RATION COMPONENTS BY LAMBS FED VARIOUS MINERAL SUPPLEMENTS

Lot No.	Ration Identification	Dry Matter Intake gm.	Nutrient Digestibility: Organic Matter Trial A [1]	Organic Matter Trial B [2]	Crude Protein Trial A	Crude Protein Trial B	Ether Extract Trial A	Ether Extract Trial B	Crude Fiber Trial A	Crude Fiber Trial B	N-Free Extract Trial A	N-Free Extract Trial B
1	Basal	651	67.9	69.7	68.2	71.9	74.3	72.6	56.2	58.9	70.7	73.4
2	Basal + minerals	660	68.1	69.8	69.6	70.1	77.2	75.0	57.6	56.1	70.2	72.1
3	Basal + alf. ash	686	75.7	73.8	74.0	70.4	86.6	87.7	72.6	68.0	76.0	75.1
4	Basal + syn. alf. ash	690	71.9	74.5	70.0	71.7	83.9	86.7	66.2	69.4	73.0	75.7

[1] Average of 8 successive 3-day trials.
[2] Average of 3 successive 3-day trials, lambs on rations of lots 1 and 3 and lots 2 and 4 were exchanged.

that under our conditions the beneficial effect of alfalfa ash or the synthetic ash was due solely to cobalt, although the possibility that cobalt is involved in combination with other materials is not excluded by these findings. Since the addition of a mixture of common minerals, namely, sodium, potassium, copper, iron, magnesium, manganese, iron and zinc, to the basal ration which contained supplemental cobalt and iodine was without effect, these elements appear not to be solely responsible for the beneficial effects of alfalfa ash. We suggest that the beneficial effect of added minerals in the form of alfalfa ash or synthetic ash may be due to: (1) the addition of some other essential micro-nutrient contained in the natural ash and present as a contaminant in the salts, (2) an increase in the total ash content of a low-ash ration with a subsequent favorable effect of undetermined nature on the ruminal bacteria, or (3) some combination of known nutrients which are present in inadequate or unbalanced amount. In this connection, it should be noted that the addition of alfalfa ash did not improve the digestibility of a prairie hay basal ration naturally higher in ash (Tillman *et al.*, 1954a), but did improve the digestibility of a cottonseed hull basal ration (Tillman *et al.*, 1954b). Further studies are in progress in an attempt to elucidate the mechanism of action.

TABLE 3. ANALYSIS OF VARIANCE OF APPARENT DIGESTION COEFFICIENTS

Source	D.F.	Mean Squares				
		Organic Matter	Crude Protein	Ether Extract	Crude Fiber	N-Free Extract
Treatment	3	60.19**	26.09	144.02**	267.80**	30.76**
Lot 1 vs. 2, 3, 4	1	51.85*	31.04	219.52**	293.50*	17.60
Lot 2 vs. 3, 4	1	103.51**	19.07	194.84**	449.19**	59.57**
Lot 3 vs. 4	1	25.20	28.12	17.70	66.69	15.12
Error	14	8.93	11.29	13.15	33.72	5.37

* P less than .05.
** P less than .01.

This experiment was designed to permit observations on progressive changes in digestion coefficients following placement on the variously supplemented rations, as was suggested by earlier preliminary results (Chappel, 1952). Serial three-day collection periods, however, failed to reveal any consistent pattern of change. Whether this was due to the fact that adjustment had already occurred during the ten-day pre-

liminary period or whether the previous observations were merely fortuitous is not known.

It may be worthwhile noting the influence of the added minerals on the appetite of lambs. Rations containing alfalfa ash or synthetic alfalfa ash were readily consumed. In contrast, throughout this trial as well as in preceding and subsequent ones, difficulty was encountered in keeping the animals "on feed" on the basal rations. Lambs on the basal ration did, however, clean up their feed during all digestion trials. It was further noted in preliminary studies that inclusion of calcium as $CaCl_2$ or the replacement of $CaHPO_4$ with $Ca(H_2PO_4)_2$ brought about a sharp reduction in feed consumption. Since $CaCl_2$ is an acid-forming salt and since the monobasic calcium phosphate is more acidic than the dibasic form, the synthetic alfalfa ash may promote better appetite by virtue of its higher alkalinity. Similarly, natural alfalfa ash, which also has a high pH, might also have its favorable influence on appetite for the same reason.

The implications of these findings in the utilization of practical rations low in ash are obvious. Whether the benefits derived from their application to practical feeding of ruminants will be justifiable requires additional study. Such studies are also currently in progress at this station.

Summary

Digestion experiments were conducted with lambs to investigate the effect of various supplements to a ration in which corncobs was the main roughage. The ration was designed to be adequate with respect to major nutrients. It contained supplemental salt, cobalt and iodine but was low in total ash. Addition of a mixture of common nutrient mineral elements was without effect. However, the addition of either the ash of alfalfa or a synthetic alfalfa ash (a mixture of purified salts simulating the composition of alfalfa ash) resulted in highly significant increases in the digestion of organic matter and crude fiber fractions of the ration. Appetite of the lambs was also improved by either of these mineral additions.

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A STUDY OF SHEEP DURING STARVATION AND WATER DEPRIVATION [1]

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THERE is little information available on the components of body-weight loss when farm animals are starved or deprived of water. Farm animals may be deprived of water or food during extremely poor feed and water conditions, or during a long period of shipment. The type of losses which occur when experimental animals are deprived of feed and water overnight before weighing in order to decrease the variation due to fill is at least of academic interest.

The main component of the weight loss of animals during starvation and water deprivation would be water; and, consequently, attention should be directed toward the changes in the water compartments of the body. There are very few reports in literature on experiments with farm animals in which attention was given to the changes in the body fluid. Hix *et al.* (1953) presents the first information on this important aspect. However, much work has been done with experimental animals and humans (Adolph, 1947; Elkinton, 1950; McQuarrie, 1945; and Peters, 1944).

This report presents information from a balance study with sheep which were deprived of feed and water for 36 hours. Since the use of sodium chloride to regulate the consumption of supplemental feed by range livestock has become widespread and since a few livestock men in California are also using salt to limit the consumption of concentrate of growing and fattening cattle on pasture, part of the sheep were placed on the high sodium chloride intake before being shrunk for 36 hours.

Experimental

Four crossbred wethers were used for the experiment; two were fed the basal ration and two were fed the basal ration plus 11 percent sodium chloride (table 1). The basal ration was composed of 84.5 percent alfalfa hay, 15 percent barley, and 0.5 percent salt and contained 58 percent TDN which had been determined in a previous diges-

[1] The technical assistance of Gene Martin and Thurmond McWhorter is gratefully acknowledged.

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tion trial. The sheep were fed twice daily a constant amount of ration which would supply them with their TDN requirement for maintenance calculated according to the method of Brody *et al.* (1934). Water was offered *ad libitum* during the experimental period excepting in the shrink period and accurate measurements were made of water consumed.

TABLE 1. BALANCE STUDY

Category of Interest	Sheep No.	Basal				High NaCl			
		Pre-Shrink	Shrink	Water	Post-Shrink	Pre-Shrink	Shrink	Water	Post-Shrink
Period, hrs.		76	36	9	96	76	36	9	96
Daily feed intake[2]									
Basal	1	831[1]	....	....	742	817[1]	....	....	788
	2	921[1]	....	....	894	817[1]	....	....	693
Sodium chloride	1	....	....	....	....	110	....	....	106
	2	....	....	....	....	110	....	....	94
Water intake, ml./ kilo body wt./ hour	1	2.8	....	2.4	2.9	9.4	....	2.0	9.1
	2	2.4	....	0.5	3.0	7.3	....	0.2	7.1
Nitrogen balance, g.	1	8.0	−19.2	−4.2	20.9	9.8	−13.8	−1.3	19.9
	2	17.0	−19.1	−4.3	35.4	10.7	−11.4	−0.5	26.0
K balance, g.	1	7.5	−6.6	−0.5	9.8	3.6	−7.6	−0.8	8.1
	2	9.3	−7.4	−0.9	14.6	2.4	−9.0	−0.2	6.7
Body weight, kg.	1	34.0	31.8	32.2	32.9	35.6	32.2	32.4	34.5
	2	39.7	37.6	37.6	39.0	35.1	32.7	32.9	34.7
Na space liters	1	10.2	10.5	10.5	10.6	10.8	8.9	8.9	8.4
	2	12.0	12.0	12.0	12.0	10.5	9.6	9.6	10.8
Cl space, liters	1	10.2	9.0	9.2	9.5	10.8	6.6	6.9	8.2
	2	12.0	10.4	10.5	11.0	10.5	7.8	7.4	8.4

[1] This amount supplies the maintenance requirement for TDN (Brody *et al.*, 1934). The basal ration included 0.5% sodium chloride.
[2] Dry matter basis.

During a preliminary period of 35 days, the animals were fed the respective rations. After they had been brought on feed and had consumed their entire ration for a period of 7 days, they were placed in metabolism stalls. The regime in metabolism stalls was as follows: For 3 days the sheep were fed and watered; on the fourth day they were given their morning feed and water at 4 A.M.; at 11 A.M. they were shrunk for 36 hours without feed or water; on the 36th hour of the shrink period they were given water *ad libitum* for the next nine hours; another four day post-shrink period was allowed in which the sheep were left in the metabolism stalls and offered their water and ration. The sheep were weighed, bled and fecal and urine collections were made before each morning feeding and on the 6th, 12th, 24th,

and 36th hour of the shrink and at the end of the water only period. During the above mentioned regime the sheep were in the metabolism cages constantly except during weighing. Urine and feces were handled in the usual way to prevent any loss of constituents.

The blood serum was analyzed for albumin, sodium, and chloride, and hematocrits were run on the whole blood. Albumin was separated from the blood serum by the method of Kingsly (1940) and determined as outlined by Greenberg (1929). Blood chlorides were determined by the method of Schales and Schales (1941), and the sodium was determined directly on the blood serum with the use of a flame photometer. Urine was analyzed for sodium, potassium, chloride, and nitrogen. Feed and feces were analyzed for potassium, sodium, chloride, nitrogen, ash and dry matter. Sodium and potassium were determined directly on the urine with the flame photometer and after wet ashing on the feed and feces. The method of Fraps and Brown (1947) was used for the determination of chlorides; the Kjeldahl procedure was used for nitrogen determinations. Extracellular fluid was calculated as outlined by Elkinton and Taffel (1942).

Results and Discussion

Observations on the eating and drinking habits of the sheep revealed that they responded in a manner somewhat unexpected (table 1). During the three days preliminary to the shrink, sheep on the basal ration consumed from 2.5 to 3.8 ml. of water per kilo body weight per hour while the two sheep on the salt ration consumed from 7.3 to 9.4 ml. of water per kilo body weight per hour. The difference between these two groups of sheep was apparently due to the large amount of sodium chloride that had to be excreted in the urine of the high salt sheep. When water was offered to these sheep after 36 hours, they did not seem to desire any large amount of water even though large losses of water occurred during the shrink. This was true for both groups of sheep. During this nine hour period they consumed from 0.2 to 2.4 ml. of water per kilo of body weight per hour. At the end of this 9 hour period the sheep then were offered their ration and water. Immediately their water consumption rose to equal the amount consumed before the shrink period. In this case it appeared that water intake was regulated by food intake. The observation has been made by Adolph and associates (1947) in experiments with men after they had been without water for some time that drinking was much greater and a larger amount of water was consumed when the men were offered food at the same time they were offered water.

During the post-shrink period it was difficult to get the sheep back on feed. Every sheep refused feed at one or more feeding during the post-shrink period.

Figure 1 presents information on changes in some of the blood constituents. It can be noted that no consistent changes could be

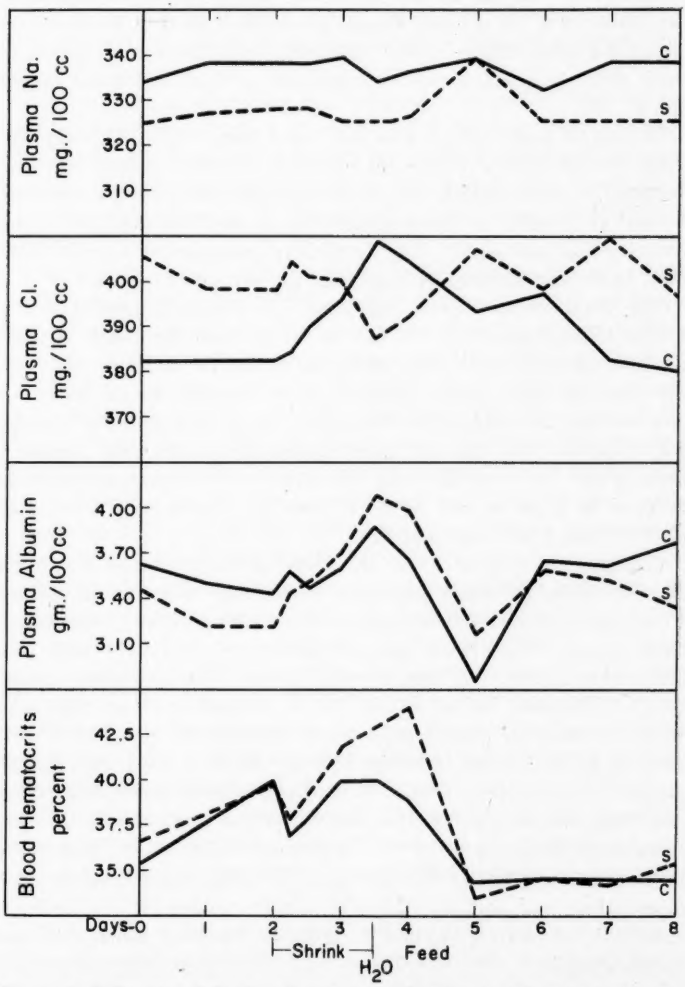

Figure 1. Influence of food and water deprivation on blood constituents.

observed in the sodium and chloride levels of the blood serum. Also no differences can be noted between the sheep fed the two types of rations. Black *et al.* (1944) and Adolph (1947) with humans, Painter *et al.* (1948) and Kanter (1953) with dogs, and Dicker (1949) with rats in water privation had shown an increase in electrolytes in long periods of dehydration. In our experiment the period of food and water deprivation was for a much shorter period of time than in the above mentioned work. Heller (1949) did not demonstrate an increase in these electrolytes when rats were deprived of food and water for 24 hours.

Striking changes occurred in the blood hematocrits. Although the sheep on the control ration did not show definite changes in blood hematocrits when shrunk for 36 hours, those fed the high salt feed showed an increase in blood hematocrits at the 24th hour, and upon receiving feed and water, blood hematocrits dropped to a point somewhat below the previous average from the pre-shrink period.

The blood serum albumin responded in a manner somewhat similar to the blood hematocrits. It can be noted that the blood albumin remained constant during the entire period for the control sheep with the exception of a sudden drop in blood albumin on the day they received feed and water after the shrink. An increase in blood albumin was noted for the high salt sheep during the shrink and reached a peak at the 36th hour. As with the control sheep, the blood albumin dropped to a sub-normal level and then rose again on the 2nd day after receiving feed and water.

Changes which occurred in the blood hematocrits and the blood albumin during the shrink period for the high salt sheep would indicate a decrease in plasma volume. After a severe period of water deprivation Siegel *et al.* (1947) with rats and Adolph *et al.* (1947) with men observed an increase in blood hematocrits or a rise in plasma specific gravity. However, Painter *et al.* (1948) pointed out that they considered changes in plasma protein and hematocrits were not reliable as an index of volume reduction in dogs. Heller (1949) observed no changes in hematocrits after a 24 hour period of dehydration in adult rats while Nadal *et al.* (1941) observed only a small change in blood hematocrits and plasma protein in humans subjected to mild water deprivation. Our results with sheep on the basal ration confirm these observations and indicate that the plasma volume is not changed sufficiently to create a significant change in the blood hematocrits and serum albumin.

The amount of urine excreted by the high salt sheep during the preliminary period was much greater than was excreted by the sheep on the basal ration (figure 2). During the shrink period the urine excretion rate of the high salt sheep decreased rapidly and at the 36th hour was reduced to the excretion rate of the sheep on the basal ration. The excretion rate remained the same during the nine hour period when the sheep were offered water only. When both groups were offered food and water the amount of urine excreted by the high salt sheep rose to a very high level.

Urinary chloride excretion rate followed very closely that of the total urine volume excreted. It wasn't until the 36th hour of shrink that the amount of chloride excreted by the high salt sheep decreased to about the chloride level excreted by the sheep on the basal ration. The pattern of sodium excretion was very similar to that of the chloride excretion.

Observations on the rate of excretion of potassium in the urine indicated that as the shrink period progressed the amount of potassium excreted in the urine dropped to a very low level. No differences were observed between patterns of potassium excretion by the sheep on either the high salt or the basal ration. It can be observed, however, that a larger amount of potassium was excreted by the sheep on the high salt ration during the preliminary period and during the recovery period. This was due to a larger amount of potassium in the high salt ration. Even though the ration components were from the same feeds, a larger amount of potassium was found by analysis to be present in the ration of the high salt sheep.

For the high salt sheep, the pattern of the nitrogen excretion rate in the urine was very similar to that of potassium. It was high during the preliminary period and dropped to a low level during the shrink period and then again rose during the recovery period. The above pattern was not followed by the two sheep on the basal ration. While the rate of nitrogen excretion in the urine dropped during the shrink period, it did not drop to the same extent. The explanation of these differences is not entirely clear at the present time. If there was a greater breakdown of tissue protein, then one would also expect an increase in the amount of potassium excreted in the urine since potassium is present in the body largely in the intracellular phase (Elkinton *et al.* 1944).

Body weight losses were greatest for all sheep during the first 12 hours and tended to level off to the 36th hour (figure 3). The allowance

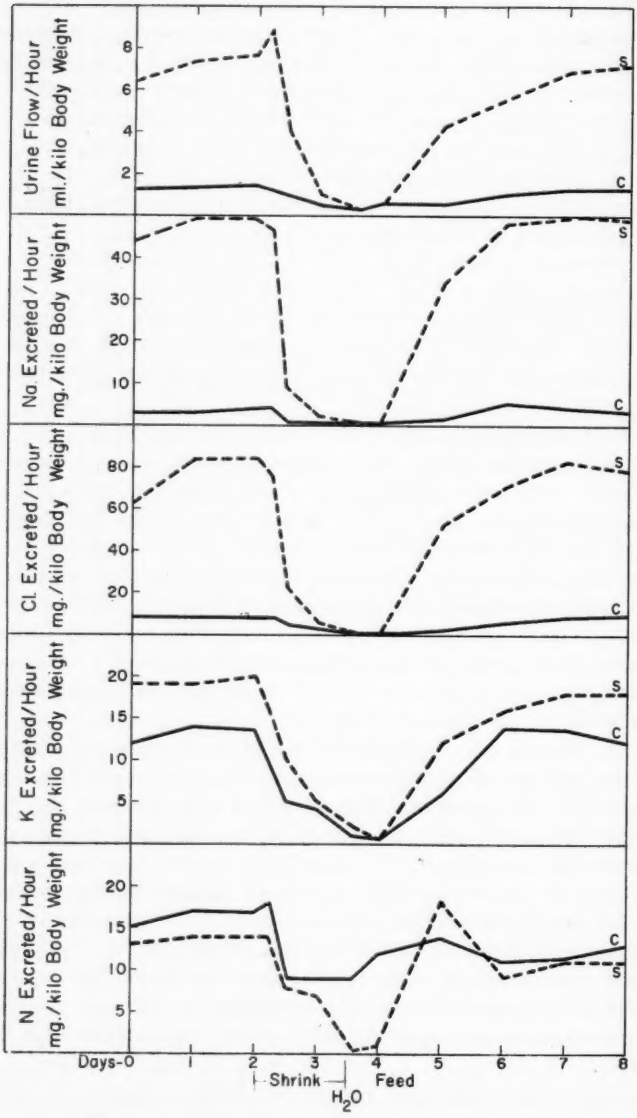

Figure 2. Urinary constituents excretion rates.

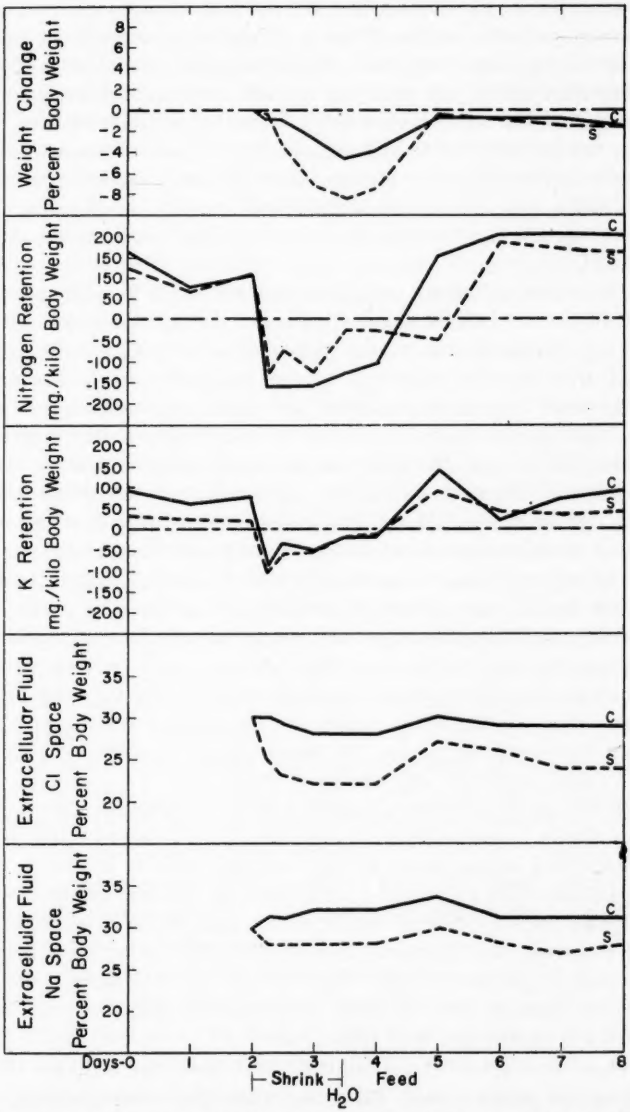

Figure 3. Influence of food and water deprivation on body weight, potassium and nitrogen retention; and sodium chloride space.

of water for the nine hour period without feed did not cause any great increases in body weight. When feed and water were given to the sheep at the same time after the shrink period their body weights approached that of the pre-shrink period; however, for the four day period after the shrink their weights did not quite attain the level that they had previously. The high salt sheep lost a larger amount of body weight during the shrink period. While the sheep receiving the high salt ration lost 7.5 percent of their body weight, the sheep fed the basal ration lost approximately 5 percent of their body weight during the shrink.

The potassium balance trend as shown in figure 3 generally parallels that of the body weight changes; however, the high salt sheep did not lose any more potassium during the shrink period than did the control sheep. Both were in negative K balance during the shrink. The grams of potassium lost during the shrink period were approximately the same for both groups of sheep (table 1). One difference that might be pointed out is that the sheep on the basal ration retained a larger amount of potassium during the pre-shrink and post-shrink period than did the high salt sheep. The reason for this is not clear. A longer period of observation might have smoothed out these differences.

The nitrogen balance figures presented in figure 3 and in table 1 do not parallel the changes in body weight; the greatest weight loss was obtained with the high salt sheep, and the largest amount of nitrogen was lost by the sheep on the basal ration. As was pointed out above, the large nitrogen loss which occurred from the sheep on the basal ration was due to the urinary loss. An amount of nitrogen, which more than compensated for the shrink loss, was retained during the post-shrink period by both groups of sheep.

Indications of the extracellular fluid were calculated from the sodium and chloride balances (figure 3 and table 1). An assumed initial extracellular fluid volume of 30 percent was used (Hix *et al.*, 1953). The extracellular fluid calculated from sodium and chloride balances, while following the same general trends, do not agree as far as exact figures are concerned. In this study it was found that the greatest changes occurred in the extracellular fluid when it was calculated from the chloride balance. This has been found also by Elkinton and Taffel (1942) in experiments with dogs.

There was a loss of extracellular fluid from the high salt sheep during the shrink period. Calculated from the sodium balance, this

amounted to 41 and 59 percent of the body weight loss. However, when one calculates the loss of weight due to extracellular fluid from the chloride balance it equals either 100 percent or exceeds that of the body weight loss. The reason for the difference in these observations is due to the chloride that continued to be excreted in greater amounts during the shrink period. Even though these observations do not agree as to the exact amount of extracellular fluid loss, they do indicate that, when sheep fed a high salt ration are shrunk, a large part of the body weight loss is probably loss of extracellular fluid. The changes in the blood albumins and hematocrits agree with these observations. The loss of extracellular fluid is correlated with the rise in blood hematocrits and plasma albumin.

The results of the extracellular fluid, as indicated by the sodium and chloride balance of the sheep fed the basal ration, do not follow the same trends as for the sheep fed the high salt rations. The sodium balance of the sheep fed the basal ration indicates no change whatsoever in extracellular fluid. This would indicate that the loss in body weight of these sheep during the shrink period was made up primarily of intracellular fluid. Observations from the chloride space indicate a drop in extracellular fluid during the shrink period. As for the sheep on the high salt ration, the reason for the difference in chloride space and the sodium space was due to greater excretion of chloride. The sodium space as far as the basal sheep were concerned might give a clearer indication of the change in the two body fluid compartments. The plasma albumin and the blood hematocrits did not change to any great extent during the shrink period and therefore correlate quite closely with the fact that the sodium space did not change during the shrink period. The fact that the basal sheep showed a greater excretion of nitrogen (figure 2), possibly due to a breakdown in body tissue, is in accord with the supposition that a large part of the body weight loss was due to intracellular fluid loss. Hix *et al.* (1953) have noted good agreement between directly determined extracellular fluid and that calculated from the sodium balance.

These experiments in general indicate that sheep when fed a ration which is low in salt, lose body weight which is made up largely of intracellular fluid while the sheep on the high salt ration lose body weight which is composed of extracellular fluid and intracellular fluid. Indications of this were obtained from the blood hematocrits and the

blood albumin level and from the changes which occurred in the body fluids of the body as calculated from the sodium and chloride balances.

The information derived from this experiment when applied to such conditions as the loss of weight of animals in transit from a shipping point is that a real loss in weight occurs and not merely a decrease in body weight due to fill. The sheep on the basal ration showed an actual loss of nitrogen and potassium and in addition showed indications of having quite a decrease in intracellular fluid. During the 4 day post-shrink period when fed rations which were equal to their maintainence requirements the sheep never did quite regain their original weight. Anything that would give an animal an extra fill such as receiving large amount of sodium chloride causes an extra weight loss when the animals are shrunk. This extra weight loss appears to be partly extracellular fluid and it appeared that this loss was immediately corrected with feed and water. In other words, any loss in weight which might be due to extracellular fluid can be fairly easily corrected. If there is loss of intracellular fluid, however, this situation is not as easily corrected.

Summary

A study was made of sheep in metabolism stalls deprived of feed and water for 36 hours. Two sheep received a ration that supplied the maintenance requirements of TDN, two received the above ration plus 11 percent sodium chloride. A three day pre-shrink, and a 36-hour shrink without feed or water followed by a four day post-shrink period, was the experimental design. Water consumption was low after 36 hours shrink, and did not reach pre-shrink levels until feed was offered. Feed refusals occurred after the shrink.

Changes in blood plasma sodium and chloride did not show trends during the experiment. A rise in blood hematocrits and plasma albumin of the high sodium chloride sheep was noted during the 36 hours shrink, while no changes in these constituents were observed in the sheep on the basal ration.

Urinary volume was much larger for the sheep on the high salt rations during the pre-shrink and post-shrink periods than for the sheep on the basal ration. During the shrink period both groups of sheep showed a marked decrease in the rate of urine flow and at the end of the shrink urine flow for both groups of sheep was the same. The patterns of urinary sodium and chloride excretions rates were similar in both groups of sheep and resembled the pattern of urine flow. In

the high salt sheep, the rate of nitrogen excretion in the urine dropped to a very low level during the shrink. The rate of urinary nitrogen excretion by the sheep fed basal ration did not drop to any great extent during the period of water and food deprivation.

While the sheep receiving the high salt ration lost 7.5 percent of their body weight, the sheep on the basal ration lost approximately 5 percent of their body weight during the shrink. Negative potassium balances, equal for both groups of sheep, were noted during the shrink. The nitrogen balance was negative during the shrink for both groups of sheep, but a larger amount of nitrogen was lost by the sheep fed the basal ration. An amount of nitrogen was retained during the post-shrink period which more than compensated for the loss of nitrogen during the shrink. Extracellular fluid calculated from the sodium balance indicated no change during the shrink for the sheep fed the basal ration, but did indicate a loss of extracellular fluid by the high salt sheep. Calculations of the extracellular fluid from the chloride balance showed a loss of extracellular fluid for the sheep fed the basal ration and a very large loss by the sheep fed the high sodium chloride ration.

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VARIATION IN THIAMINE AND NIACIN CONTENT OF RAW LAMB MUSCLE

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PREVIOUS work (Cover, Dilsaver and Hays, 1947) has indicated considerable variation in thiamine and niacin content of meat from different lamb carcasses even when samples were taken from the same position. This seems rather remarkable in view of the fact that sheep are known not to require these vitamins in their feed. A deficiency of either of these vitamins is unlikely in healthy lambs.

In that report, the meat from the triangles of 4 lambs had been composited and subsamples from the composite had been obtained for analysis. Highly significant differences were obtained among 6 such composites. Because these samples were composites, it seemed desirable to make analyses on meat from individual lambs to see if differences would be found among individuals as well as among the composites and to see if anything in the known history of the lambs might be related to the expected differences.

Experimental

Lambs were available from three experiments in which various levels of aureomycin had been fed.[1] There was a possibility that the aureomycin treatments might have changed the rumen flora in such a way as to reduce thiamine synthesis in the rumen and thus the amount of thiamine in the muscles.

In Experiment One, the lambs were slaughtered in March 1952 at about 1 year of age. They were fine wool lambs from West Texas. Only 9 lambs were fed in this preliminary test with aureomycin and all of them were used for vitamin determinations. In Experiment Two, the lambs were slaughtered in February 1953 at about 1 year of age. They were among those used by Bridges, Miller, Kammlade and Kunkel (1953) in their first experiment. Meat from only 4 lambs in each of the 3 lots could be prepared for analysis, making a total of only 12 lambs analyzed from the 27 living at the end of the experiment. Average carcass weights for these 3 lots were very close—44.9, 44.0, and 44.7.

[1] These experiments were carried on by the Department of Animal Husbandry.

For this reason, the carcasses for analysis were selected from those with weights nearest the lot average. In Experiment Three, the lambs were slaughtered in June 1953 at about 1½ years of age. They were among those used by Bridges *et al.* (1953) in their third experiment. Meat from only 27 of the 62 lambs living at the end of the experiment was available for the tests.

The carcasses were stored 7 to 8 days at 34–36° F. In Experiment One, the meat for analysis was taken from only position in the carcass —the triangle. It included neck, breasts, shoulders and shanks. In Experiments Two and Three, samples were obtained from two positions in the carcass—leg as well as triangle. The meat for analysis in all of the experiments was boned, the separable fat removed and the lean meat cut into approximately 1-inch cubes. The cubes of meat were mixed separately for each position in each carcass and several large samples of approximately 2 pounds each were obtained from each mix. Each of these samples was wrapped in foil and frozen. In Experiment One, meat from all of the lambs was analyzed concurrently, two samples from each lamb one week and two more samples from each lamb 5 weeks later. In Experiments Two and Three, where two positions were included, only 2 samples were analyzed from each position in each lamb.

Although two packages from one mix were analyzed at one time, the samples were kept separate during the entire laboratory procedure: they were ground separately; the solutions were made up separately; and separate standard curves were used for the microbiological determination of niacin; but the same technician made all of the analyses. Thus the variation among the packages from one position in one animal included all phases of laboratory technique such as mixing the meat cubes and grinding the samples as well as all steps in the chemical analyses. In addition, the usual duplicate or triplicate determinations were made on aliquots from each package.

The methods for moisture and fat were essentially those of AOAC and for thiamine and niacin were essentially those described in Methods of Vitamin Assay of the Association of Vitamin Chemists.

Results and Discussion

The average vitamin content of the raw meat from lambs fed different levels of aureomycin in the three experiments is given in table 1. The thiamine and niacin values are given on the moist basis and on the dry fat-free basis because of the importance of each for different uses.

Since the samples contained unequal amounts of fat the comparisons of B vitamin content have been made on the dry fat-free basis. An

TABLE 1. VITAMIN CONTENT OF RAW MEAT FROM LAMBS[1] FED DIFFERENT LEVELS OF AUREOMYCIN

Position	Aureomycin per Pound of Concentrates	Number of Lambs	Mean Thiamine Content: Moist Basis mcg./gm.	Mean Thiamine Content: Dry Fat-Free mcg./gm.	Mean Niacin Content: Moist Basis mcg./gm.	Mean Niacin Content: Dry Fat-Free mcg./gm.
			Experiment One			
Triangle	None	3	1.0	5.0	41	215
	9 mg.	3	0.9	4.7	42	226
	36 mg.	3	1.2	6.5	40	221
		9	1.0	5.4	41	221
			Experiment Two			
Triangle	None	4	1.5	7.7	40	211
	1.1 mg.	4	1.4	7.0	46	234
	4.3 mg.	4	1.3	6.6	44	230
		12	1.4	7.1	43	225
Leg	None	4	1.9	9.3	47	229
	1.1 mg.	4	1.9	8.8	54	257
	4.3 mg.	4	1.7	8.0	52	251
		12	1.8	8.7	51	246
			Experiment Three			
Triangle	None	8	1.1	5.9	46	236
	1.25 mg.	7	0.9	4.6	45	233
	5.00 mg.	7	1.2	6.2	46	240
	15.00 mg.	5	1.2	6.0	47	242
		27	1.1	5.7	46	238
Leg	None	8	1.5	7.3	55	265
	1.25 mg.	7	1.2	5.8	54	257
	5.00 mg.	7	1.6	7.7	55	263
	15.00 mg.	5	1.6	7.6	55	266
		27	1.5	7.1	55	263

[1] Tables showing gains per day, carcass weight, carcass grade, thiamine content and niacin content for each individual lamb are available in a separate mimeographed report entitled "Supplementary Tables for Variation in B Vitamin Content of Lamb." Copies of these tables may be obtained from the Agricultural Information Office, Texas A. & M. College System, College Station, Texas.

analysis of variance was made on the dry fat-free values from each experiment (table 2). Variation in vitamin content among aureomycin treatments was small in comparison to that of individual lambs within treatments. It was true in each of the three experiments and for each of the two vitamins. Thus no relationship was found between aureomycin feeding and the thiamine and niacin content of the meat. Variation in vitamin content among lambs within treatments was large in

relation to that of the samples from the same mix or to that of position in animals within treatments. It was true in each of the three experiments and for each of the two vitamins. It indicates a significant difference in vitamin content of meat from different animals. No clue to the cause of these individual differences in vitamin content was apparent.

TABLE 2. OUTLINE OF STATISTICAL ANALYSIS

Source of Variation	March 1952		February 1953		June 1953	
	Degrees Freedom	Mean Square	Degrees Freedom	Mean Square	Degrees Freedom	Mean Square
			Thiamine Content			
Treatments [1]	2	10.68	2	5.82	3	18.26
Positions [1]	..	....	1	30.65**	1	52.65**
P x T [1]	..	....	2	0.08	3	0.22
Animals within T [2]	6	9.46**	9	1.86**	22	6.57**
P x A/T [3]	..	....	9	0.03	22	0.27**
Samples	27	0.05	24	0.06	56	0.04
Total	35		47		107	
			Niacin Content			
Treatments [1]	2	366	2	2,993	3	359
Positions [1]	..	...	1	5,250**	1	17,455**
P x T [1]	..	...	2	41	3	47
Animals within T [2]	6	497**	9	710**	22	748**
P x A/T [3]	..	...	9	32	22	169**
Samples	27	75	24	27	56	29
Total	35		47		107	

[1] Error term was A within T.
[2] Error term was S for March test, P x A within T for February and June tests.
[3] Error term was S.

Average thiamine and niacin content in the leg was somewhat higher than in the triangle (table 1). The difference was highly significant statistically (table 2). Variation among individual muscles within an animal has been shown for thiamine in pigs by Pyke (1940) and for thiamine and niacin in pigs by Rice, Daly, Beuk and Robinson (1945). The data in this study indicate similar variation for lamb. Comparison of variation of vitamin content among different animals should be made on meat from the same muscle or the same muscle groups. The impor-

tance of this may be indicated in the June tests. The large number of lambs required considerable extra help with the fat separations. It was not possible under these conditions to be as meticulous in saving every bit of lean as in the other tests. It is thought that small variations in muscle composition of the composites may have caused the high mean square (table 2) for P $\times$ A/T for this test only. However, it was not high enough to affect the significance of A within T.

Speculation as to the causes of variation in vitamin content of meat are difficult because of the lack of clues. Thiamine production by microorganisms in the rumen is assumed. Any interruption in its production, or change in its rate of absorption or metabolism might produce variations in thiamine content of the muscles of different animals. The attempt in this study to interfere with the production of thiamine in the rumen appeared to be unsuccessful as a means of controlling the thiamine content of the meat. It is assumed, therefore, that the antibiotic aureomycin had no effect on the thiamine-producing microorganisms, at least under the conditions of these experiments. Perhaps, when the microbiology of the rumen is more clearly understood clues to the cause of thiamine variation among animals may be forthcoming.

Conclusions

1. No relationship was found between aureomycin treatments and the thiamine or niacin content of the meat of these lambs.

2. Significant variation in thiamine and niacin content of the meat from different lambs within the treatments was observed.

3. Leg had somewhat higher content of thiamine and niacin than triangle which indicates that comparisons of variation of vitamin content among different animals should be made on meat from the same position in the carcass or on the same muscle groups.

4. No clue to the cause of variation in vitamin content of meat from different lambs was found in the history of these animals.

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A COMPARISON OF THE EFFECT OF STILBESTROL ON THE GROWTH RESPONSE OF LAMBS OF DIFFERENT AGE AND SEX

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THE use of stilbestrol to increase the rate of gain in lambs was first reported by Andrews *et al.* (1949). These observations were repeated and extended by subsequent investigators (Jordan, 1950; Pope *et al.*, 1950; O'Mary *et al.*, 1952; Bell *et al.*, 1954). Studies by Clegg and Cole (1954) indicate that, insofar as heifers and steers are concerned, the growth response to treatment is more effective in the animal maintained on a high concentrate ration. Furthermore, heifers even on a high energy diet were not as responsive as steers maintained under the same conditions. In addition to the dietary regime, the age at which the animal is treated appears to play a role in the effectiveness of treatment. Jordan and Dinusson (1950) reported no significant increase in the rate of gain of suckling lambs weighing approximately 25 lb. when treated with 12 mg. of stilbestrol. Perry *et al.* (1951) obtained a significant increase in the growth rate of suckling lambs weighing 46 lb. when treated with 12 mg. to 24 mg. of stilbestrol. Jordan (1953) reported no increase in the rate of gain of suckling lambs treated with 12 mg. of stilbestrol at an average initial weight of approximately 40 lb. In lambs weighing approximately 48 lb. at the time when treatment was instigated, a slight increase in rate of growth occurred, but this difference was not significant.

Methods

With the assistance of the Agricultural Extension personnel and many cooperators, it was possible to conduct a number of experiments involving different breeds, different locations, different ages, and different dietary conditions, consisting of suckling, suckling with creep feeding

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concentrates, native grass forage, irrigated pasture and pasture with supplementary concentrates. The general plan of each trial was to select randomly equal numbers of wether and ewe lambs to be treated; and a similar number to be left as the untreated controls. In most cases, treatment was done at the time of docking, marking and castration. Treatment consisted of one 12 mg. or 15 mg. pellet of stilbestrol implanted subcutaneously in the ear. The lambs were either individually identified with a paint brand or metal ear tag or were identified as a group by an ear notch or paint brand. All lambs were weighed immediately following treatment and again at the end of the trial. An excess of feed was available at all times throughout the experimental period. Table 1 summarizes the general information for each trial. In addition to these field trials, one controlled experiment was conducted. In this trial, Suffolk-crossbred wethers were separated randomly into three lots and individually identified. Lot I served as the control group. The animals of Lot II were treated with one 12 mg. pellet of stilbestrol implanted subcutaneously in the ear. The animals of Lot III were treated with three 12 mg. pellets of stilbestrol (36 mg.) also implanted in the ear. The average initial weight of the lambs in all lots was approximately 63 lb. The entire ration for all groups was furnished from Sudan pasture. Individual weights of all animals were obtained once every two weeks following an overnight stand without access to food or water. The total elapsed time between treatment and slaughter was 84 days. Weights of the adrenal glands and the dried anterior lobe of the pituitary gland were recorded subsequent to slaughter.

Results

Effect of Sex on the Growth Response to Stilbestrol

There is no significant difference in the effect of stilbestrol on the growth response obtained between treated wether and ewe lambs. Table 2 summarizes the data obtained from all the trials and when a comparison is made between the individual animals of the same trial, little difference is noted between the average daily gain of similarly treated groups regardless of sex. Since there is no apparent sex interaction, it is possible to group the two sexes for each trial.

Effect of Age on the Growth Response to Stilbestrol

Suckling lambs treated at an approximate initial weight of 20 lb. with 12 or 15 mg. of stilbestrol gain significantly more than their

TABLE 1. AN OUTLINE LISTING THE PERTINENT DATA FOR EACH EXPERIMENT ON THE EFFECT OF STILBESTROL ON THE GROWTH OF LAMBS [1]

Trial No.	No. of Treated Lambs [2]	Breed	Sex [3]	Range of Initial Wt. Lb.	Length of Exp. Period Days	Ration [4]
I [5]	10	Suffolk-Corriedale	w	20.2	130	Native grass and irrig. pasture (ladino clover and mixed grasses)—no supplement.
II	20	Suffolk-Corriedale	w & e	14.0–27.5	120	Native grass and irrig. pasture (ladino clover and mixed grasses); Supplement—alfalfa meal, molasses and barley.
III	17	Romeldale and Columbia crossbreds	w & e	11.2–25.6	51	Irrig. pasture (ladino clover and mixed grasses) —no supplement
IV	6	Suffolk-Corriedale	w & e	21.0–34.0	106	Irrig. pasture (ladino clover and mixed grasses) —no supplement
V	40	Hampshire	w & e	20.0–58.0	70	Irrig. pasture (ladino clover and mixed grasses) —no supplement
VI [5]	20	Columbia-Rambouillet	w & e	21.0–45.0	99	Pasture (clover and grasses) plus grain hay. Lambs creep fed grd. alfalfa hay and rolled oats.
VII	20	Suffolk crossbred	w & e	25.5–46.0	57	Irrig. pasture (ladino clover and mixed grasses) —no supplement
VIII	20	Suffolk-Corriedale	w & e	25.0–50.5	78	Irrig. pasture (ladino clover and mixed grasses) —no supplement
IX	48	Suffolk crossbred	w	52.0–73.0	84	Sudan pasture—no supplement.
X [5]	62	Hampshire and Suffolk crossbreds	w & e	41.0–85.0	59	Pasture (ladino clover and grasses) plus supplement—barley, grd. alfalfa hay and dried figs.
XI [5]	35	Suffolk	w & e	60.0	72	First 51 days pasture (clover and grasses) last 21 days—mixture 66% barley, 33% rye, 1% salt, 1#/hd/day.
XII	20	Suffolk-Corriedale	w & e	44.0–73.3	64	Irrigated pasture (ladino clover and mixed grasses)—no supplement.

[1] Treatment consisted of one 12 mg. or 15 mg. pellet of stilbestrol implanted in the ear except Trial IX in which a third group received 36 mg.
[2] Approximately the same number of animals in each trial served as controls.
[3] w—wether; e—ewe.
[4] The description of the ration indicates the feed to which both dams and lambs or lambs alone were exposed throughout the duration of the trial.
[5] In these trials the animals were weighed as groups. In all others individual weights were obtained.

TABLE 2. EFFECT OF STILBESTROL ON WETHER (W) AND EWE (E) LAMBS TREATED AT DIFFERENT AGES

Trial No.	No.	Sex[1]	Treatment	Days on Trial	Ave. Init. Wt.	Ave. Final Wt.	Total Gain	Ave. Daily Gain
I[2]	10	W	None	130	20.4	61.8	41.4	.318
	10	W	15 mg.	130	20.1	67.3	47.2	.363
II	10	W	None	120	19.7	60.5	40.8	.340
	10	W	12 mg.	120	19.2	66.8	47.6	.397
	10	E	None	120	18.5	57.5	39.0	.325
	10	E	12 mg.	120	20.4	69.6	49.2**	.410
III	7	W	None	51	18.2	40.3	22.1	.433
	8	W	15 mg.	51	18.6	44.2	25.6	.502
	8	E	None	51	17.9	37.4	19.5	.382
	9	E	15 mg.	51	19.1	43.3	24.2*	.475
IV	3	W	None	106	27.5	79.2	51.7	.488
	3	W	15 mg.	106	26.0	81.5	55.5*	.524
	3	E	None	106	32.7	84.5	51.8	.489
	3	E	15 mg.	106	28.8	89.8	61.0	.575
V	21	W	None	70	38.9	89.3	50.4	.720
	18	W	12 mg.	70	35.8	91.4	55.6*	.794
	19	E	None	70	31.1	85.7	48.6	.694
	22	E	12 mg.	70	41.1	97.9	56.8**	.811
VI[2]	10	W	None	99	33.0	90.3	57.3	.579
	10	W	15 mg.	99	32.9	92.7	59.8	.604
	10	E	None	99	32.3	88.3	56.0	.566
	10	E	15 mg.	99	32.4	92.0	59.6	.602
VII	10	W	None	57	33.6	61.8	28.2	.495
	10	W	12 mg.	57	30.0	63.9	33.9**	.595
	10	E	None	57	30.8	56.0	25.2	.442
	10	E	12 mg.	57	28.6	57.8	29.2	.512
VIII	10	W	None	78	38.0	65.8	27.8	.356
	10	W	12 mg.	78	39.1	71.8	32.7	.419
	10	E	None	78	38.4	64.4	26.0	.333
	10	E	12 mg.	78	36.0	66.0	30.0	.385
IX	16	W	None	84	62.9	88.8	25.8	.307
	15	W	12 mg.	84	62.2	92.2	30.0*	.357
	17	W	36 mg.	84	63.1	94.0	30.8**	.367
X[2]	64	W & E	None	59	69.2	82.9	13.7	.232
	62	W & E	15 mg.	59	68.9	87.4	18.5	.314
XI[2]	16	W	None	72	61.5	82.9	21.4	.297
	15	W	12 mg.	72	63.2	91.0	27.8	.386
	19	E	None	72	60.0	87.1	27.1	.376
	20	E	12 mg.	72	58.9	90.0	31.1	.432
XII	10	W	None	64	57.9	86.8	28.9	.452
	10	W	12 mg.	64	63.3	97.3	34.0	.531
	10	E	None	64	52.7	76.5	23.8	.372
	9	E	12 mg.	64	51.5	84.3	32.8**	.513

* Significantly larger than controls P less than .05.
** Significantly larger than controls P less than .01.
[1] W=wether lamb E=ewe lamb.
[2] The animals in these groups were not weighed as individuals, thus no test of significance can be applied.

untreated controls, (table 3). This increase in gain over controls can also be observed in lambs treated at approximately 30 lb. and at approximately 60 lb. In every trial in which individual weights were recorded, this difference in gain was significant. A comparison of the

TABLE 3. A COMPARISON OF THE COMBINED AVERAGE DAILY GAIN OF WETHER AND EWE LAMBS BETWEEN TREATMENTS BEGUN AT DIFFERENT AGES

Trial No.	Lambs	Total Gain lb.	Ave. Daily Gain lb.	% Increase in Ave. Daily Gain Over Controls
Average Initial Weight Approximately 20 Pounds When Treated				
I[1]	Control	41.4	.318	
	Treated	47.2	.363	+14.2
II	Control	40.0	.333	
	Treated	48.4**	.403	+21.0
III	Control	20.8	.408	
	Treated	24.5*	.480	+17.6
	Average % Increase			+17.6
Average Initial Weight between 30 and 40 Pounds When Treated				
IV	Control	51.7	.488	
	Treated	58.3*	.550	+12.7
V	Control	49.6	.709	
	Treated	55.8**	.797	+12.3
VI[1]	Control	56.7	.573	
	Treated	59.7	.603	+ 5.2
VII	Control	27.1	.475	
	Treated	32.5**	.570	+18.9
VIII	Control	26.9	.345	
	Treated	31.4*	.403	+16.8
	Average % Increase			+13.2
Average Initial Weight Between 60 and 70 Pounds When Treated				
IX	Control	25.8	.307	
	Treated	30.4**	.362	+17.9
X[1]	Control	13.7	.232	
	Treated	18.5	.314	+35.3
XI[1]	Control	24.4	.338	
	Treated	29.7	.413	+19.2
XII	Control	27.0	.422	
	Treated	33.4**	.522	+23.7
	Average % Increase			+24.0

* Significantly larger than controls P less than .05.
** Significantly larger than controls P less than .01.
[1] The animals in these trials were not weighed as individuals thus no test of significance can be applied.

percent increase in average daily gain over the control levels indicates little difference in the response regardless of the age at which treatment was initiated. It is possible that lambs treated at 50 to 70 lb. may be somewhat more responsive than younger animals, but our data do not support this concept. Previous studies by Clegg and Cole (1954) have indicated that when steers on a high concentrate ration are treated with 60 mg. of stilbestrol, the average increase in daily gain over the controls amounted to 25–30 percent. This value compares with an average increase in daily gain of approximately 17 percent for lambs treated with 12–15 mg. of stilbestrol.

Effect of Dietary Regime on the Growth Response to Stilbestrol

In California most lambs are grass fattened on range forage and irrigated pasture. Thus it is of particular practical value to determine the effects of different dietary conditions on the response to stilbestrol treatments. From table 1 it can be noted that in Trial II, VI, X, and XI the lambs received a supplement containing grain (barley) and a high quality roughage (alfalfa hay or meal). In the balance of the trials no supplement was fed—the ration consisting mostly of native range grass or irrigated pasture (ladino clover and mixed grasses).

When the average percent increase in rate of gain over the controls for the trials receiving supplement is compared with those not receiving the concentrate, no difference can be observed. The treatment, therefore, appears to be as effective for lambs on grass pasture as it is for those on a high concentrate ration.

Effect of Stilbestrol Treatment on Endocrine Weights

In trial IX the weights of the adrenal glands and pituitary glands were obtained when the animals were slaughtered. As in cattle, sheep likewise have significantly larger adrenal and pituitary glands (P less than .05). The average weight of the control paired adrenal gland was 2.9 gm. and the dried anterior lobe of the pituitary was 126.6 mg. The average weight of the treated paired adrenal glands was 3.3 gm. and the dried anterior lobe of the pituitary was 151.7 mg. Bell *et al.* (1954) reported significantly enlarged cowpers glands, seminal vesicles and prostate glands in treated wethers. We, likewise, observed this enlargement. In the treated wethers of Trial IX there was a noticeable stimulation of the mammary gland development. These glands contained a milky secretion at the time of slaughter, Jordan *et al.* (1953) have previously reported similar effects.

Discussion

A summary of our findings indicates that age, sex, or dietary regime does not affect the response to stilbestrol treatment in lambs under the conditions of the experimental procedures here reported. Jordan and Dinusson (1950) and Jordan (1953) did not obtain a significant increase in gain of suckling lambs treated at 25 lb., at 40 lb., and at 48 lb. We, on the other hand, found that the treatment was equally effective regardless of age of treatment. It is true that in order to display this difference a large number of animals was used. The fact that there is no difference in response regardless of sex or dietary regime is interesting in view of our previous findings in cattle in which steers gained more rapidly than heifers and only very small increased gains could be obtained in animals receiving a diet consisting largely of roughage (Clegg and Cole, 1954.) The cause of this difference in effect of treatment between the two species is not apparent at this time.

In view of those reports describing a seriously high incidence of death loss resulting from vaginal or rectal prolapse as well as urinary blockage, (Jordan, 1953; Bell *et al.*, 1954) it is of value to determine the number of animals which failed to complete the test. This is possible only in those trials where the lambs were individually identified. Thus, out of 150 treated animals, seven ewe and three wether lambs failed to finish. In the control group which also consisted of approximately 150 animals, six ewe lambs and one wether lamb failed to finish. We are unable to determine whether the identification of these animals was lost or whether death actually occurred. There were three recorded cases of vaginal prolapse in the ewe lambs, and one known case of rectal prolapse in the wether lambs of the treated groups. No cases were reported in the controls. Many of the treated ewes, however, showed evidence of edema and hyperemia in the vaginal area.

Summary

Twelve different trials consisting of 318 treated animals of both sexes and an equal number of controls were conducted in different regions of the state of California. These trails were varied to include animals ranging from an initial weight at the start of treatment of approximately 20 lb. up to approximately 60 lb. In all except one trial, the animals received one 12 mg. pellet or one 15 mg. pellet implanted in the ear. In the exception, an additional group of wether lambs received 3 pellets (36 mg.) of stilbestrol.

The results indicate a significant increase in rate of gain due to treatment regardless of age, sex or dietary regime. Animals of younger ages responded as effectively to treatment as older animals. There was no difference in the percent increase in rate of gain of treated animals of either sex, nor did differences in dietary regime affect the response. There was no difference in the rate of gain of wether lambs treated with 12 mg. from those treated with 36 mg. of stilbestrol.

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MILK CONSUMPTION AND GROWTH OF SUCKLING LAMBS

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THIS work was undertaken to study the effects of milk production of the ewe on the weight and condition of the lamb with particular emphasis to fat-lamb production. Rapid growth is highly desirable in fat-lamb production because (1) rate of gain probably is correlated with efficiency of feed utilization, (2) per unit costs are reduced when lambs are on the farm a shorter length of time, (3) cyclic market trends usually favor the earlier marketed spring lambs. In addition, rate of gain is usually positively related with condition, the most important single criterion of market grade. A knowledge of the conditions essential for most rapid growth of lambs is therefore important from an economic viewpoint and also as an aid in selection when weight gain and condition are the endpoints.

Materials and Methods

Eighteen single lambs and five pairs of twin lambs produced by aged purebred Hampshire ewes were used in this study. All lambs were dropped during the period December 24, 1953 to January 29, 1954. Lambs and ewes were weighed within twenty-four hours following lambing. These weights were used as lamb birth weight and ewe weight respectively. The width of the ewe's udder just anterior to the teat placement was taken as a measure of udder size. Milk consumption determinations were made at weekly intervals from 1 week to 12 weeks of age. Determinations were made in the following manner: Lambs were isolated from their dams at 4:30 P.M. At 7:30 A.M., 10:30 A.M., 1:30 P.M., and 4:30 P.M. of the following day, lambs were weighed, allowed to nurse their dams, and weighed again. The weight increase while nursing during the four sucking intervals was summated and this amount used as an estimate of the daily milk consumption of the lambs for that week. In case of twin lambs, both lambs were allowed to nurse at the same time. In all instances, all lambs were raised by their own dams and not by foster dams.

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Results

Average daily milk consumption of five groups of lambs divided on the basis of milk consumption during the first four week periods are given in table 1. The daily milk consumption of the lamb or of both twin lambs is used as an estimation of the daily milk production of the ewe for that weekly period. The lactation curves of all groups plotted from data in table 1 are quite similar; milk production is highest during the first four weeks, declines rapidly during the next four weeks, and declines less rapidly during the remaining periods. The average daily milk production of ewes suckling twins is very similar to the average daily milk production of all ewes suckling single lambs. Total milk production of ewes suckling single lambs is correlated with the weight of the ewe ($r=.74$), birth weight of the lambs ($r=.50$), and udder width at lambing ($r=.47$).

Weights of lambs in the groups in table 1 are given in table 2. The importance of milk consumption is demonstrated by the difference in growth between twins and single lambs, largely due to sharing of the available milk supply by two lambs rather than one. A second indication of the importance of milk consumption is shown by the growth rate of single lambs from high and low milk producing ewes. Weight advantages produced by higher milk consumption are maintained throughout the 16 week period.

The correlations between milk consumed and average daily gain during the various four week periods are given in table 3. Average daily gain of lambs is highly correlated with milk consumption during the first four weeks. As the lambs grow older, the correlation between milk consumption and average daily gain decreases rapidly and daily gain from 12 to 16 weeks is not significantly correlated with milk consumption during the previous periods. Correlations between gain during the early periods and milk consumption during subsequent periods are a reflection of the correlation between early gain and early milk consumption and the correlations ($r=.80$ to $.90$) between early and later milk consumption and may not represent a direct cause-and-effect mechanism.

Average daily gain of lambs to 16 weeks is correlated with total milk consumption ($r=.83$) of the lamb to 12 weeks. The regression function of average daily gain on milk consumption for this period is $+.00143$ indicating, for each increase of one lb. in milk consumption of the lamb, a corresponding increase of .00143 lb. in average daily

TABLE 1. MILK CONSUMPTION OF HAMPSHIRE LAMBS FROM BIRTH TO 12 WEEKS OF AGE[1]

Class	Total Pounds Consumed		No per Group	Average Daily Milk Consumption (lb.) by Weekly Periods											
	Birth to 4 Weeks	Birth to 12 Weeks		1	2	3	4	5	6	7	8	9	10	11	12
Singles	90–100	216.6	4	3.3	3.5	3.7	3.1	2.8	2.8	2.5	2.2	1.8	1.8	2.0	1.7
	80–90	191.2	4	3.1	3.0	3.0	2.8	2.3	2.0	2.1	1.8	2.1	2.0	1.8	1.2
	70–80	164.9	4	2.9	2.9	2.5	2.4	2.1	2.0	1.9	1.5	1.4	1.4	1.5	1.1
	60–70	135.4	3	2.6	2.5	2.1	2.1	2.0	1.6	0.9	1.0	1.2	1.2	1.2	1.1
	less than 60	95.1	3	1.9	1.3	1.6	1.3	1.2	1.2	1.0	0.9	0.9	1.0	1.0	0.5
Singles average		165.7	18	2.8	2.7	2.7	2.4	2.1	2.0	1.8	1.5	1.5	1.5	1.5	1.2
Twins (per set)		174.0	5	2.8	3.0	2.8	2.6	2.3	1.9	1.8	1.8	1.7	1.5	1.6	1.2

[1] Divided into sub-groups on the basis of total milk consumption from birth to 4 weeks.

TABLE 2. GROWTH OF HAMPSHIRE LAMBS FROM BIRTH TO 12 WEEKS OF AGE [1]

Class	Milk Consumed (lb.) Birth to 4 Weeks	No. per Group	Average Weight (lb.) of Lambs at Various Ages				
			Birth	4 Weeks	8 Weeks	12 Weeks	16 Weeks
Singles	90–100	4	12.5	29.5	47.1	65.9	83.2
	80–90	4	10.2	26.0	41.7	58.2	76.4
	70–80	4	11.4	25.4	39.5	53.2	74.1
	60–70	3	10.7	22.7	35.4	48.8	68.0
	less than 60	3	7.9	17.3	27.5	41.6	56.4
Singles	Average	18	10.7	24.6	39.0	54.5	72.7
Twins	(per lamb)	10	7.1	15.1	24.2	36.9	53.2

[1] Divided into sub-groups on the basis of total milk consumption from birth to 4 weeks.

gain or an increase in gain for the 112 day period of 0.16 lb. (This regression function was significant at P of .01 with 16 d.f.). Average daily gain of lambs is also correlated with weight of the ewe (r=.67), birth weight of the lamb (r=.61), and udder width (r=.54). The method of multiple regression using weight of the ewe and milk consumption as independent variables indicates that after the deviations due to the regression of average daily gain on milk consumption were removed, the effect of weight of the ewe on average daily gain is quite small. Likewise, when birth weight of the lamb and milk consumption are the independent variables, there is no significant effect of birth weight of the lamb on average daily gain after the deviations due to the regression of average daily gain on milk consumption are removed. Udder width also has little effect on average daily gain when the effects of milk consumption on average daily gain are removed.

TABLE 3. CORRELATION COEFFICIENTS BETWEEN MILK CONSUMPTION OF SINGLE LAMBS AND THEIR AVERAGE DAILY GAIN WITHIN CERTAIN PERIODS [1]

Average Daily Gain during the Period	Total Milk Consumed During the Period			
	Birth to 4 Weeks	4 to 8 Weeks	8 to 12 Weeks	Birth to 12 Weeks
Birth to 4 weeks	.90	.88	.87	.93
4 to 8 weeks	.77	.80	.61	.78
8 to 12 weeks	.38	.42	.51	.45
12 to 16 weeks	.18	—.05	—.19	.00
Birth to 16 weeks	.84	.79	.71	.83

[1] Correlation coefficients in this paper of .59 or greater significant at P of .01 and of .47 or greater significant at P of .05 (16 d.f.).

The findings in this study verify an early statement by Niedig and Iddings (1919) who after preliminary studies of milk production and lamb growth declared "the greatest factor in growth is quantity of milk." In studying the production of crossbred and grade Merino ewes bred to mutton rams for fat-lamb production, Bonsma (1939) reported correlations between milk intake of the lamb and weight of the lamb during the first eleven weeks of age quite similar in magnitude to the correlations between milk consumption and average daily gain of lambs given in table 3. However, both the milk yields and gains of lambs from the Merino type ewes were much lower than milk yields and gains of the Hampshire sheep used in the present study. The work by Thomson and Thomson (1953) indicated that when milk production of Cheviot ewes was altered by depressed levels of feeding during the last six weeks of pregnancy, the growth rate of lambs was markedly decreased. Wallace (1948) observed correlation coefficients of .88 to .90 between milk consumption of lambs and their live weight increase between birth and 28 days of age, when both single and twin lambs were included. This inclusion would tend to increase the correlation since both milk consumption and weight increase were lower for the twin lambs than for single lambs. The work of Barnicoat, Logan, and Grant (1949) with high producing Romney ewes indicated that early growth (birth to 3 weeks) was not correlated with milk production of the ewe when milk production was in excess of the amount that the lamb could consume.

The present work and the work of the authors reviewed indicates that a considerable amount of variation in milk production exists between ewes within a breed. Milk production is closely associated with weight gains of the lambs. The correlations existing between milk consumption and growth of the suckling lamb are of such magnitude that the statistical efficiency of most trials designed to measure other factors affecting growth of suckling lambs would be increased by milk consumption determinations.

Summary

The weight gains of eighteen single and ten twin Hampshire lambs and the milk production of their dams were determined. Early growth and milk production were highly correlated ($r=.90$). As the lambs grew older the correlation between growth and milk production in each four week period decreased rapidly. However, the total milk production and total growth of the lamb to 16 weeks were highly correlated

(r=.83). Factors studied which were correlated with both milk production and lamb growth were weight of the ewe, udder width at lambing, and birth weight of the lamb.

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A METHOD FOR THE ANALYSIS AND COMPARATIVE PRESENTATION OF TEMPERATURE AND HUMIDITY REGIMES

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TEMPERATURE and humidity are two atmospheric conditions which must be considered together if the significance of environmental warmth for the animal is to be appreciated properly; but workers often find difficulty in handling the data. Part of this difficulty stems from the fact that the familiar expression "relative humidity" is less useful as a measure of atmospheric effects upon warm-blooded animals than is the less familiar "vapor pressure." Part of it derives from the inadequacy of present knowledge on the relative effectiveness of temperature and humidity in producing heat effects in domestic animals. This paper presents a simple method of handling observations on temperature and humidity, in whatever form they are made, in such a way that the prevailing regime is easily seen and its chief characteristics appreciated. In brief, the raw data are plotted on a psychrometric chart, which automatically indicates the values of humidity in terms of vapor pressure (and other expressions such as dew point); as well as relative humidity, permits a visual grasp of the prevailing conditions, and facilitates statistical analysis.

Relationship between "Relative Humidity" and "Vapor Pressure"

The "vapor pressure" of the air is a measure of the concentration of water vapor in the air; it is the fraction of the total barometric pressure contributed by the gaseous water molecules. It indicates the tendency for the gaseous water molecules in the air to rejoin any liquid water present on a surface. Similarly the vapor pressure of a surface is the tendency for water molecules to leave the liquid water on the surface and pass into the air. The difference between the vapor pressures of the surface, on the one hand, and the air on the other, measures the tendency for evaporation—and its resultant cooling effect—to take place. This may be expressed:

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$$E = K_e (p_s - p_a) \quad \ldots\ldots (1)$$

where E is rate of heat lost by evaporation,
K_e is a constant
p_s is vapor pressure of the surface
p_a is vapor pressure of the air

The vapor pressure of a surface is determined by the temperature of the surface and the extent of the water film on the surface. For the surface of the respiratory tract in a warm-blooded animal, these two factors remain constant, and the same is approximately true for the skin under warm to hot conditions, as long as its supply of moisture is maintained. Under these circumstances it is the vapor pressure of the air which will govern the opportunity for evaporative cooling of the animal body. It is the vapor pressure of the air, therefore, which will be the best measure of the significance of humidity for the animal.

The previous equation may be written in this case:

$$E = C - K_e p_a \quad \ldots\ldots (2)$$

where C is a constant $(= K_e p_s)$

The "relative humidity" of the air, on the other hand, is the ratio of the actual vapor pressure to the vapor pressure that the air would have if it were saturated. This may be written:

$$R = 100\, p_a / P_a \quad \ldots\ldots (3)$$

where R is the relative humidity (in %),
P_a is the saturation vapor pressure of the air at air temperature.

Since the amount of water vapor that air can hold (P_a) increases as air temperature increases, it follows that the relative humidity corresponding to a given vapor pressure decreases as temperature rises. Furthermore, the vapor pressure corresponding to a given relative humidity can be found only if the temperature of the air is also known. Because of its complex and variable relationship to vapor pressure, which is the important element in determining evaporation, relative humidity is not a good measure of humidity in so far as it affects the cooling of an animal.

The Psychrometric Chart

Unfortunately, the vapor pressure of the air cannot easily be measured directly. It is usually derived from simultaneous readings of dry- and wet-bulb temperatures, or from simultaneous readings of the dry-bulb temperature and the relative humidity.

The psychrometric chart, (figure 1), which engineers and climatologists use in calculating transfers of heat and water vapor, expresses the relationships between four climatic elements—air (dry bulb) temperature, wet bulb temperature, relative humidity, and vapor pressure

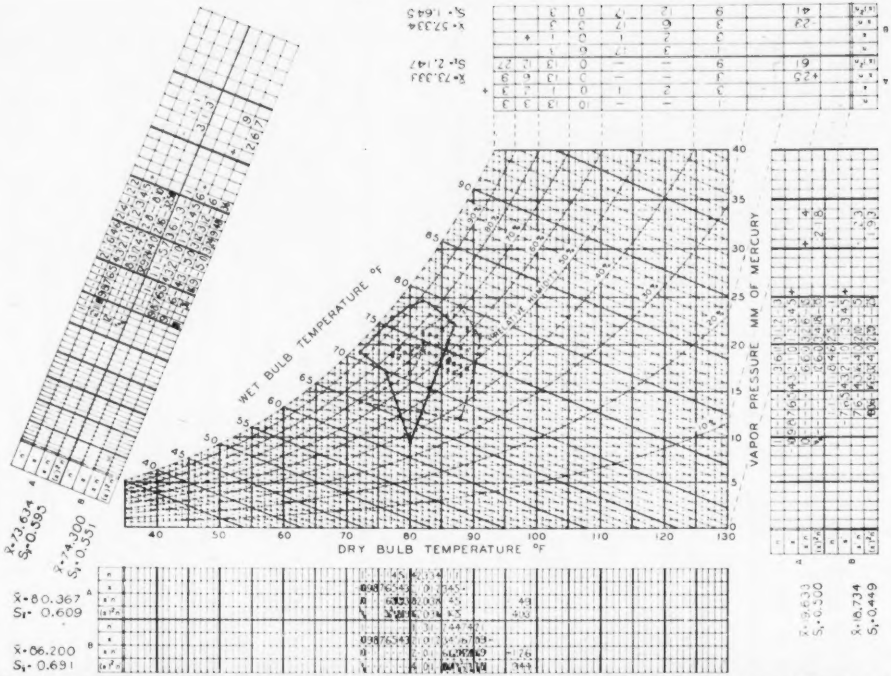

Figure 1. Psychrometric chart arranged for illustration of ranges of observed conditions and computation of statistical expressions. (Reproduced from Lee, D. H. K., "Manual of Field Studies on the Heat Tolerance of Domestic Animals," FAO Development Paper No. 38, Rome, Italy.)

—which are so inter-related that when the values of any two are known, the values of the other two are fixed and can be read from the chart. For clarity, the nature of the four elements may be summarized:

The *dry bulb temperature* is that given by an ordinary thermometer exposed to air, but protected from any important source of radiant energy. The values of dry bulb temperature in °F are marked off along the base of the chart, from which vertical lines carry the values into the chart.

The *wet bulb temperature* is that given by a thermometer encased in a damp sleeve, over which the air is moving fairly rapidly. The values of wet bulb temperature in °F are marked off along the left-hand curved margin of the chart, from which oblique lines continue the values into the chart.

The *relative humidity* may be measured directly by the change in the length of a fibre, such as a hair, as it takes up or gives off moisture. Different values of relative humidity appear on the chart as a series of curved lines.

The *vapor pressure* is not usually measured directly, but determined from the chart by entering it with two other values.

Plotting of Data

For each observation a mark is made on the chart at the point of intersection of the dry bulb and wet bulb, or dry bulb and relative humidity, lines corresponding to the observed values. Should two points coincide, a prime may be placed against the mark made for the first observation. If a third point should also coincide, a second prime can be made and so on. After all entries have been made, it may be convenient to replace the primes by numerals indicating the number of coincidences.

Plots may be made for all the observations gathered at all times of day throughout the month; but it is usually preferable to plot observations made only at two selected hours—say, 0700 and 1300, as coming closest to the coolest and hottest times. In this case, different symbols should be used for the two times, so that they can be dealt with separately in subsequent operations.

The act of plotting a point in terms of two climatic variables automatically indicates the corresponding values of the other associated climatic variables; so that if dry and wet bulb temperatures were used in making the plot, the corresponding values of relative humidity and vapor pressure are thereby indicated.

Statistical Analysis

The lines of the psychrometric chart serve to delimit classes for the statistical treatment of the plotted data. In figure 1 these have been continued into the margins to provide cells for calculation of means and standard deviations, where no calculating machine is available. Analyses for the data shown in the chart are included. If, as is often the case, original temperatures are plotted as whole numbers, without decimal fractions, then the value of each temperature class is that of its left-hand or lower boundary; but in the case of derived data, and also original data plotted with fractions, the value of each class is that of its mid-point.

Relative humidity cells have been inverted to preserve the left-to-right progression of class values, and avoid possible confusion over signs.

Interpretation

The means and standard errors of all four climatic elements should be written clearly in an appropriate place. The values for the means should coincide at some location in the center of the plotted points, and this location can be plainly marked.

It is sometimes instructive to indicate the range of variation about this mean in each of the three variables—dry bulb temperature, wet bulb temperature, vapor pressure—by a line in the direction of the variable, extending on either side of the mean for a distance equal to the standard error. (There must be a clear interval between the extremities of such lines from two means before the means can be considered significantly different.)

The visual impression is heightened if the outlying points of a sample are connected by a distinct line. It is frequently difficult to decide, however, just which are the "outlying" points—whether to swing inwards with the line to pick up an intermediate point, or to carry it straight on to the next clear outlier.

When charts prepared in this fashion for different months at the same place, or different places at the same month, are set up side by side, the differences in climatic experience at once become apparent. This is true, not only for the general position of the observations, but also for any one of the four variables. Understanding and explanation become much simpler than when the material is confined to a series of bewildering figures, scattered about in a table.

It is possible that the relative effects of temperature and humidity upon animal function may be well enough known, in the not too distant future, to be expressed in a formula. In that case, combinations of temperature and vapor pressure having the same general effect could be expressed as lines superimposed upon the psychrometric chart. Such superimposed lines would indicate the significance for the animal of the various atmospheric conditions recorded.

Illustrative Data

Reproductions of plots, with dry-bulb and wet-bulb lines omitted for clarity, are given for Jeanerette, La., in figures 2 and 3. From these charts the following observations can be made at a glance:

a. That, while temperatures at noon are markedly higher than at 6 a.m., the vapor pressures are virtually unchanged.
b. That there is some overlap between conditions at the two times.
c. That relative humidities at 6 a.m. are crowded against the saturation ceiling, but that there is considerable variability at noon.
d. That, while corresponding mean temperatures and vapor pressures are much higher in July than in March, the mean relative humidities are substantially the same.
e. That in 6 a.m. temperatures and associated vapor pressures there is much more variability in March than there is in July.
f. That noon temperatures and vapor pressures are about equally variable in March and July.
g. That if, for argument's sake, it is accepted that a wet-bulb temperature of 75° F. is the upper limit for sustained milk production, then inimical conditions occurred at noon on over half of the days in July, and even at 6 a.m. on one-third of the days.

Summary

A method is described for visualizing the significance of series of temperature and humidity readings made at different times, in different places, or under different circumstances. Each series is plotted on a psychrometric chart; statistical treatment carried out, using the chart lines as class limits; the outlying points joined to make an envelope; and the mean and standard error clearly plotted on the chart. The ease of interpretation is illustrated with data from Louisiana.

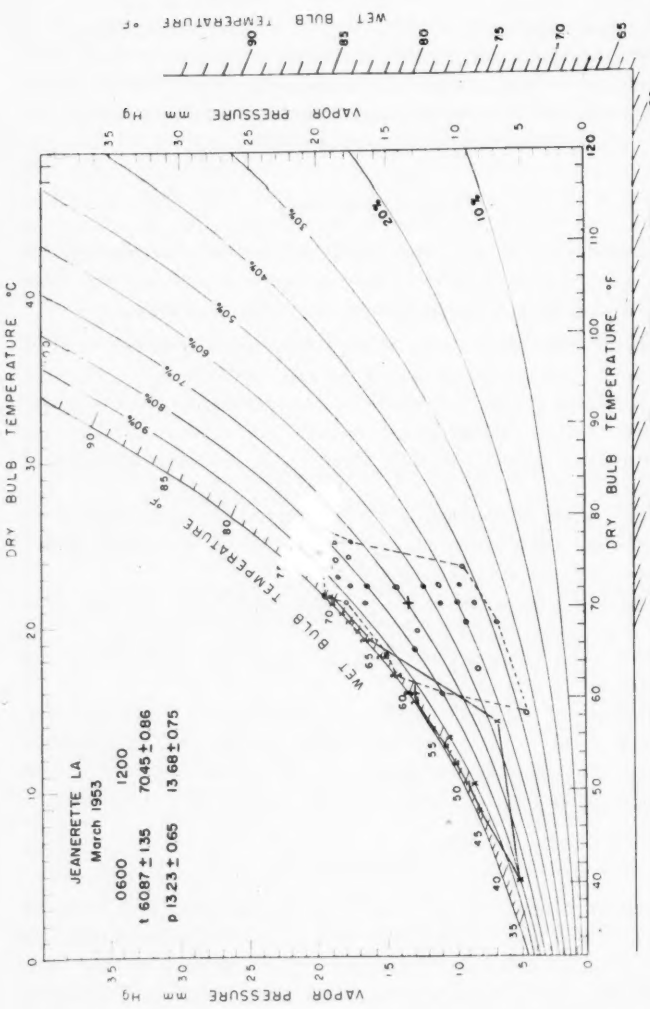

Figure 2. Observations made at Jeanerette, La., in March, 1953, plotted on psychrometric chart.

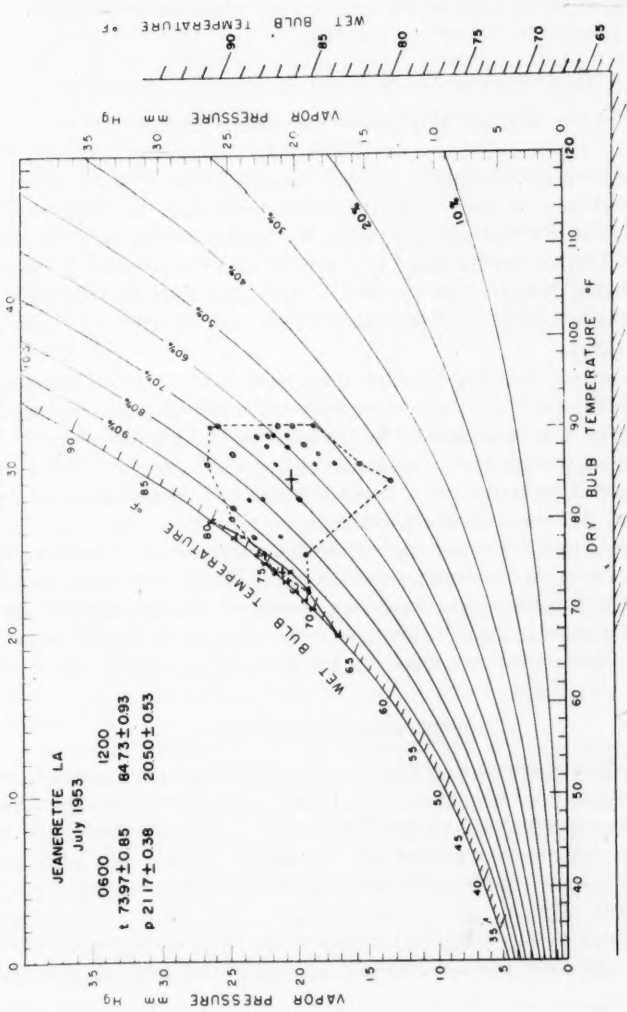

Figure 3. Observations made at Jeanerette, La., in July, 1953, plotted on psychrometric chart.

THE INHERITANCE OF A DWARF ANOMALY IN BEEF CATTLE[1]

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THE frequent production of dwarf calves and the resultant concern manifested by beef cattle breeders prompted an investigation of dwarfism by the Arizona Agricultural Experiment Station in 1948. The Arizona studies were confined to a definite dwarf type found in Hereford cattle; however, the presence of the same form of dwarfism in the Aberdeen-Angus and Shorthorn breeds was reported by Gregory *et al.* (1951).

The general description published by Johnson *et al.* (1950) identifies the specific dwarfism to which the following report pertains. Additional descriptive data were provided by Lindley (1951), Carroll *et al.* (1951), and Gregory *et al.* (1951, 1952, and 1953). Craft and Orr (1924) set forth the characteristics of a dwarf-like Hereford steer that may have been of the same morphological type.

Since a preparatory survey indicated the dwarfism to be of genetic origin, the mode of inheritance was studied. The results of four breeding tests comprising the study are presented in this paper. Dwarf breeding animals were employed in three of the tests, and no reports of like tests have been found by the authors in scientific literature.

Experimental Procedure

Preliminary genealogical studies indicated a simple, autosomal recessive gene to the basic cause of the Hereford dwarfism under investigation. An experimental plan was then devised to test the validity of the genetic hypothesis suggested by the initial studies. The program, embodying four separate although supplementary tests, involved horned Herefords only.

Precautions were taken in Tests I through IV to avoid complications that might have arisen if comprest animals, mated *inter se*, had con-

[1] The authors are grateful for the data and the livestock contributed by cooperating breeders, for the financial aid and the records supplied by the American Hereford Association, and for the dwarf animals obtained by Mr. Dan W. Clarke of Tucson, Arizona. Thanks are extended to Drs. W. J. Pistor, V. H. Fisher, and R. E. Reed for veterinary assistance and to Mr. T. P. Jardine for the pedigree studies.

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tributed to the data. Stonaker [2] obtained evidence that comprest type in Hereford cattle is the result of a gene acting with partial dominance and that two comprest genes produce a dwarf anomaly. Although crooked legs are associated with comprest dwarfs, there is seemingly no existing assurance that such dwarfs can be differentiated invariably from those considered in this publication; consequently, the necessity for the precautionary measures is obvious.

Since Stonaker expressed the opinion that Colorado Domino 68 (Registration No. 1812883) is generally considered to be the original source of the comprest gene, the precautionary measures used in the breeding tests were based on this premise. Pedigrees were checked for the presence of comprest ancestry. The extent of the pedigree studies is noted in the following summary of procedures applicable to each breeding test.

Test I

The test initially undertaken provided a phenotypic ratio of normal and dwarf progeny resulting from matings of purebred males and females with established dwarf production records. The majority of the data used in this test were obtained from cooperating breeders in the western states. Additional data were procured from the station experimental herd. The breeders provided phenotypic diagnoses of the test progeny in their respective herds, and diagnoses in the Experiment Station herd were made by the authors. At least one dwarf calf, from each of the herds involved, was examined by the authors to provide reasonable assurance that the proper dwarf anomaly was under scrutiny.

A record of supposedly normal calves, stillborn or dying within one month after birth, was maintained. It was found that dwarf characteristics were not always manifested to an appreciable degree for about one month after birth, and the diagnosticians were inclined to classify calves as dwarfs only if positive phenotypic evidence was at hand. Consequently, the possibilities of error were considered when calves that failed to survive for at least one month were classified normal.

As an adjunct to Test I, the dwarfs produced in private herds and in the Experiment Station herd were tabulated by sexes for the determination of a sex ratio.

The pedigrees of all sires, reported to have produced dwarf calves in

[2] Animal Husbandman, Colorado Agricultural and Mechanical College, Fort Collins, Colorado. Personal communication.

the herds that supplied the phenotypic ratio data, were found free of comprest ancestry. This was likewise true of the sires in five of seven herds that contributed data for the establishment of the sex ratio; the owners of the two remaining herds stated that no comprest breeding was involved. As an added precaution, a substantial number of pedigrees from the two latter herds were checked, but no evidence of comprest breeding was found.

Test II

For Test II, started simultaneously with the initial test, a dwarf breeding herd was established. Purebred calves exhibiting the aberration were obtained at weaning age and developed by the Experiment Station. The dwarfs were then mated *inter se* at 18 months of age or older, and the phenotypes of the resulting progeny were recorded.

The dwarf breeding animals used in Test II did not descend from Colorado Domino 68. These animals were purebreds, and all pedigrees were checked.

Test III

Test III was initiated while Tests I and II were in progress. In this third test, dwarf bulls were used on phenotypically normal females that had produced dwarfs previously. The phenotypic classifications of the progeny were recorded.

Pedigree examinations here again revealed no evidence of recognized comprest breeding. The pedigrees of the dwarf bulls and all but one of the females were studied. The female for which records were not available was a grade Hereford.

Test IV

In the fourth test, a dwarf sire was used on a group of two-year-old heifers from a Hereford herd in which the dwarf anomaly had not been recognized. This test was conducted to provide added evidence concerning the inheritance of the dwarfism and to supply measurement data required in another phase of the dwarf research program.

The dwarf bull used in Test IV had no comprest ancestry. The females were obtained from an unregistered purebred herd, and an attempt to extend the applicable pedigrees proved unsuccessful.

Results and Discussion

Test I

This initial test was designed to indicate the frequency with which dwarf calves would occur when Hereford males and females with established dwarf production records were mated *inter se*. Data were obtained from the records of four cooperating breeders; and in-so-far as could be determined, the records were complete. Additional information was obtained from the herd established by the Experiment Station, and the records of the animals involved were complete also. The post-probant analyses of the data accumulated are shown in table 1, where

TABLE 1. THE PHENOTYPIC RATIO ENCOUNTERED IN A STUDY OF THE PROGENY FROM HETEROZYGOUS MATINGS

Basis for Calculations	Progeny					Chi Square
	Observed [1]			Expected		
	Total	Normal	Dwarf	Normal	Dwarf	
Field diagnoses	90	66	24	67.5	22.5	0.059
Presumption that all calves dying prior to 1 month of age were dwarfs	90	62	28	67.5	22.5	1.481

[1] Post-probant matings only.

it may be seen that normal and dwarf calves occurred in a ratio of approximately 3:1.

Two different analyses of the results are shown in table 1. In the first, the observed frequencies were based on the assumption that the phenotypes were correctly identified by the breeders or Experiment Station personnel involved. The second was based on the presumption that countable post-probant calves, reported normal but dead at birth or dying within one month thereafter, were actually dwarfs. This supposition was considered in view of observations that dwarf characteristics were not always obvious at birth, that such characteristics sometimes developed at a relatively slow rate, and that there was little inclination toward dwarf diagnoses unless positive evidence existed.

Four countable post-probant calves that were reported normal died prior to one month of age or were stillborn. Three of the losses occurred in a private herd and the fourth occurred in the Experiment Station herd. The latter calf, one of a pair of twin heifers, was stillborn as the

result of a difficult parturition. The surviving twin was a true dwarf. This may have been the first of several sets of dwarf-normal twins of which the authors have been informed. Although the dead calf appeared to be of normal phenotype, the classification was not substantiated because the animal failed to survive.

Data for the calculation of a secondary sex ratio were obtained from six privately owned herds and the Experiment Station herd. The value of chi square shown in table 2 indicates ample probability that the observed deviation from equality could have been due to chance alone. The data supplied by the seven herds comprised a heterogeneous group, but the heterogeneity chi square was insignificant at the five percent

TABLE 2. THE SEX RATIO ENCOUNTERED IN A STUDY OF HEREFORD DWARFS

Observed			Expected[1]		Chi Square
Total	Male	Female	Male	Female	
244	127	117	122	122	0.332

[1] Based upon information cited by Lush (1945).

probability level. With two exceptions, the herd records from which the sex ratio data were obtained appeared to be complete. Five dwarfs in one herd and two in another were not recorded by sex; however, the omissions seemingly reflected no intentional selectivity.

The post-probant analyses shown in table 1 and the sex ratio studies summarized in table 2 indicate that the form of dwarfism considered in this report is conditioned by a single autosomal recessive gene with complete penetrance. The term "recessive" is considered justified by the absence of concrete evidence of heterozygous expression in both sexes. The results of this study support the hypothesis first advanced by Johnson *et al.* (1950) and the statement of Lush and Hazel (1952). They also support the findings of Gregory *et al.* (1953).

Test II

The results of five dwarf × dwarf matings comprising the second breeding test are reported in table 3. These matings involved four dwarf females and two dwarf sires. Five dwarf calves were produced, in agreement with expectations based on the hypothesis that an autosomal recessive gene conditions the dwarf anomaly. Although only one of

the calves lived for an appreciable length of time after birth, the dwarf phenotype was obvious in all five. The abnormalities were, however, no more extreme than those observed in a number of dwarfs produced by heterozygous × heterozygous matings.

Two calves, in addition to those discussed, were conceived; but they were not classifiable. The first of these, a four-month old fetus, was found in a badly decomposed state following the death of the dam; the second, a premature calf, was destroyed by predators before the abortion was discovered.

TABLE 3. THE RESULTS OF TEST MATINGS INVOLVING DWARF BREEDING STOCK

Matings		Progeny					
		Observed				Expected	
Females	Males	Total	Normal	Undetermined	Dwarf	Normal	Dwarf
Dwarf	× Dwarf	5	0	0	5	0	5
Heterozygous	× Dwarf	6	2	0	4	3	3
Undetermined Genotype	× Dwarf	7	4	3	0	–	–

Test III

Test III consisted of six heterozygous × dwarf matings. The results of these matings are shown in table 3. Four purebred cows and one grade cow of Hereford breeding, all having previously dropped dwarf calves, were mated with a dwarf bull. The grade cow was mated the same way a second time, thus accounting for the sixth calf.

Based on the hypothesis that a single autosomal recessive gene conditions dwarfism, Test III should have produced normal and dwarf phenotypes in equal numbers. As shown in table 3, a slight deviation from the expected ratio occurred; but the table of Warwick (1932) indicates that the observed ratio is likely to appear in tests of this scope about 23 percent of the time. In view of the probability indicated, evidence to discredit the hypothesis upon which the expectations were based appears lacking.

Test IV

For this fourth and final breeding test, 10 Hereford heifers were obtained from a herd in which the dwarf anomaly had never been recognized. These unregistered purebred females were exposed to a

dwarf bull which, up to the time this test was initiated, had sired nothing but dwarf calves when used in Tests II and III. Seven of the heifers conceived readily. Repeated services failed to settle the remaining three, and they were eliminated from the test.

As indicated in table 3, the results of Test IV were not entirely predictable. The genotypes of the females were not established prior to the test, but the history of the herd from whence they came did suggest a strong possibility that the dwarf gene was lacking or that the frequency was low. The chances of obtaining some phenotypically normal calves were, therefore, quite encouraging.

Seven calves were produced in this test, but only four survived. The surviving calves were phenotypically normal beyond question. Of the remaining three, two were stillborn and the other suffered from an apparent nervous affliction which resulted in its death at two weeks of age. The stillborn calves were large animals exhibiting no recognizable dwarf characteristics; however, the absence of absolute diagnostic techniques precluded definite phenotypic classifications. Measurements of the calf suffering from the nervous affliction were compared with both dwarf and normal measurements, but the phenotype was not identified conclusively. Because of circumstances described, this calf was also placed in the questionable category.

Test IV, although it produced some questionable results, did provide a few phenotypically normal calves, as anticipated. Thus, no disparaging reflection was cast upon the conclusion dictated by the results of the tests previously discussed. The uncertainty occasioned by calf losses did emphasize the need for diagnostic techniques permitting the phenotypic classification of calves at birth.

Summary

The inheritance of a dwarf anomaly, known to occur frequently in Hereford cattle, was studied. Four breeding tests were conducted to determine the mode of inheritance. The results of these tests indicated that the dwarfism is attributable to an autosomal recessive gene with complete penetrance.

In the first test, ninety heterozygous $\times$ heterozygous matings produced normal and dwarf offspring in a phenotypic ratio of 3:1. A sex ratio of 1:1 was observed in the dwarf population studied.

Test II was comprised of five dwarf $\times$ dwarf matings. The resulting progeny were dwarfs, but the abnormal characteristics were no more

extreme than those exhibited by a number of dwarf offspring from heterozygous × heterozygous matings.

In Test III, a limited number of heterozygous cows were mated with dwarf bulls (six matings). The progeny appeared in a normal-dwarf phenotypic ratio of about 1:1.

A dwarf sire was used on females of undetermined genotype in Test IV (seven matings). Dwarfism had not been recognized in the herd from which the females were obtained. The progeny that survived were normal. Stillbirths or early, postnatal mortality precluded the substantiation of a few phenotypic classifitations. The need for positive methods of identifying the dwarf phenotype in the event of early death losses was pointed out.

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HERITABILITY OF GROWTH, BEEF CHARACTERS AND BODY MEASUREMENTS IN MILKING SHORTHORN STEERS

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ESTIMATES of heritability for characters in farm animals help one to understand the extent to which the characters of the animals in one generation may influence those of the animals in the next generation genetically, or what proportion of change in certain characters from selected parents is to be found in the offspring. Estimates of this kind are of pratcical value to animal breeders since they indicate the genetical importance of different characters and their probable improvement in breeding programs.

Estimates of heritability for five growth characters, three beef characters, and nineteen body measurements in 58 Milking Shorthorn steers are reported in this paper. Three of the five growth characters—average daily gain, efficiency of feed utilization, and days to final weight—for 62 steers were studied by Kohli, Cook, and Dawson (1952). The 58 steers in the present paper were steers used by Kohli, Cook and Dawson in their study. Four of the steers they used were in four single-steer subgroups and were removed in the present study because the present authors believed this to be an improvement in procedure. Since the material used in this paper is not all the same as theirs, these three growth characters are restudied in this paper. The heritability estimates given in this paper differ somewhat from those published in abstract form in Genetics 37:575, 1952, due to slight changes in the technique of calculation and the omission of the four steers mentioned above.

Materials and Methods

The data used in this study were eight beef production performance records and nineteen body measurements from 58 Milking Shorthorn steers raised and recorded at the Agricultural Research Center, Beltsville, Maryland, from 1943 through 1949. The steers were the off-

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spring of 9 bulls and 51 cows. They were nursed from birth and weaned at 500 lb. live weight. They were then fed a ration of 5 parts cracked yellow corn, 3 parts ground oats, 1 part wheat bran, and 1 part linseed meal with 37 percent protein. The ration contained 75.5 percent total digestible nutrients with a total digestible protein of 10.57 percent. They received approximately one lb. No. 2 leafy alfalfa hay to every two lb. concentrate for the whole feeding period but more hay was fed during the early part of the feeding period and a higher ratio of grain for the later part of the feeding period. Concentrate was full fed and none of the animals had access to pasture. The steers were slaughtered at a live weight of approximately 900 lb., and the body measurements of each steer were taken before slaughtering and always by A. C. Cook.

The beef production performance records consisted of the records for five growth characters and three beef characters (listed in table 1). The growth characters of the steers were recorded as birth weight, days to weaning at 500 lb. live weight, days to final weight from birth to 900 lb. live weight, efficiency of feed utilization (lb. body weight gained for every 100 lb. of total digestible nutrients consumed during the feeding period), and average daily gain (lb. body weight gained each day during the feeding period). The three beef characters were slaughter grade, carcass grade and dressing percentage. The slaughter steers and the carcasses of the steers were scored by three members of a committee and the average scores of these three members were considered the slaughter grades and carcass grades of the steers. Dressing percentages were the proportions that the carcass weights, after chilling 72 hours, were to the live weights of the steers (shrunk weights) at time of slaughter.

The nineteen body measurements were four height measurements, three length measurements, three head measurements, five width measurements, three circumference measurements, and one shin bone circumference measurement. They are listed in table 2. Each measurement was taken 3 times and the average used.

The analysis of variance method as described by Fisher (1946) and Snedecor (1948) was used to estimate the variances caused by years, sires within years and errors within sires within years for each character or measurement. The paternal half-sib correlation method as suggested by Lush (1949) was used to estimate the heritability of each character. The formula, $\frac{E(E+kS)}{(E+S)^2\sqrt{1/2(k-1)kn}}$ as given by Hazel and

TABLE 1. MEAN SQUARES AND HERITABILITY ESTIMATES FOR GROWTH AND BEEF CHARACTERS IN MILKING SHORTHORN STEERS

Composition and Formulas	Average Records	Mean Squares: Years	Mean Squares: Between Sires within Years $E + kS$ ($k = 6.6$)	Mean Squares: Errors Within Sires and Years E	Heritability $\frac{4S}{S+E}$	Standard Error $\frac{4E\,(E+kS)}{(E+S)^2\sqrt{1/2(k-1)kn}}$
Degrees of freedom		6	8	43		
Growth characters						
Birth weight (lb.)	77.5	46.0	161.1	82.2	50.6	46.1
Days to weaning	206.4	790.3	1019.5	553.0	45.1	44.9
Days to final weight	437.5	1901.0	3419.6	1633.3	56.6	47.5
Efficiency (lb.)	1.56	0.0932*	0.0421	0.0399	3.2	27.2
Daily gain (lb.)	1.75	0.2439**	0.0514	0.0385	18.8	37.4
Beef characters						
Slaughter grade	67.1	18.3*	15.9	7.4	58.3	50.3
Carcass grade	68.4	22.2**	13.3*	5.7	66.7	49.8
Dressing percentage	59.9	17.6**	5.5*	2.3	69.1	50.4

E=Variance component due to environment.
S=Variance component due to sire or genetic difference.
k=Calculated average size of sub-groups.

*=Significant at 5 percent level.
**=Significant at 1 percent level.

TABLE 2. MEAN SQUARES AND HERITABILITY ESTIMATES FOR BODY MEASUREMENTS (CENTIMETER) IN MILKING SHORTHORN STEERS

Compositions and Formulas	Average Records cm.	Mean Squares: Years	Mean Squares: Between Sires Within Years E+kS (k=6.6)	Mean Squares: Errors Within Sires and Years E	Heritability 4S / S+E	Standard Error 4E (E+kS) / (E+S)²√1/2(k-1)kn
Degrees of freedom		6	8	43		
Height						
Height at withers	123.4	13.8	17.3*	7.5	65.5	49.6
Height at floor chest	59.2	4.8	12.0	7.5	33.4	41.6
Height at flank	71.9	16.8*	5.8	5.3	4.6	32.3
Depth of chest	63.1	1.5	2.9	1.7	40.1	43.8
Length						
Length of body	137.1	53.6*	4.9	17.0	0	0
Length of rump	46.0	0.3	2.5	7.2	0	0
Length of coupling	22.0	8.7	3.8	5.5	0	0
Head:						
Length of nose	24.1	2.9	0.7	1.8	0	0
Width between eyes	22.1	0.6	2.2*	1.0	63.1	48.2
Width of muzzle	15.1	1.6*	1.1	0.6	50.0	46.0
Width:						
Width at shoulder	41.5	5.0	2.6	3.2	0	0
Width at chest	37.2	6.0	4.5	3.9	9.4	34.0
Width at last ribs	54.3	26.7*	12.6	10.0	15.1	35.9
Width at loin	29.7	2.2	2.0	1.8	4.5	32.1
Width at hip	42.6	4.3	4.5	4.4	0.5	31.0
Circumference:						
Circ. at fore flank	173.8	9.7	10.3	6.5	32.3	41.2
Circ. at navel	204.0	140.5**	24.6	26.5	0	0
Circ. at rear flank	177.3	70.3**	9.0	10.8	0	0
Shin bone:						
Circ. at shin bone	18.5	0.4	0.6	0.4	33.5	41.6

E=Variance component due to environment.
S=Variance component due to sire or genetic difference.
k=Calculated average size of sub-groups.

*=Significant at 5 percent level.
**=Significant at 1 percent level.

Terrill (1945) was used to estimate standard errors for the heritability estimates (E=error variance component, S=sires variance component, k=calculated average size of the sire sub-groups, n=number of sire sub-groups).

Results and Discussion

The mean squares and heritability estimates for the growth and beef characters are given in table 1. The year variances for efficiency, daily gain and the three beef characters were significant. The sire variances for carcass grade and dressing percentage were also significant. The significant year variance indicates that the efficiency of feed utilization and the rate of daily gain in body weight for these steers were different from year to year, and the slaughter grade, carcass grade and dressing percentage of the steers were different in different years. The carcass grade and dressing percentage of the steers of different sire groups slaughtered in the same year were also different.

The heritability of birth weight was 50.6 percent, very close to the revised estimate for the Hereford steers obtained by Knapp and Clark (1950), and the estimate for the Hereford cattle on the North Platte farm obtained by Gregory *et al.* (1950). However, the estimate is higher than the estimate obtained by Dawson, Phillips and Black (1947) in beef Shorthorn cattle. It is probable that the inheritance of this character was different between the Milking Shorthorn herd and the beef Shorthorn herd at Beltsville.

The heritability for days to weaning at 500 lb. live weight was 45.1 percent. Gregory *et al.* (1950) obtained a similar heritability for the gain from birth to weaning in Hereford cattle on the Valentine farm. The heritability for days to final weight was 56.6 percent and was higher than the heritability for days to weaning. Knapp and Clark (1947) found in Hereford steers that the heritability of gain in body weight was higher for the older stage than the younger stage during the feeding period. The higher heritability for the days to final weight than that for the days to weaning is similar to the heritability found by Knapp and Clark (1947) for the weight gain in the three stages during the feeding period and indicates that the inheritance of the growth characters will be more fully expressed at the mature or older age of the animals.

The heritability for the efficiency of feed utilization and average daily gain were 3.2 and 18.8 percent. Knapp *et al.* (1946) obtained much higher estimates for these two characters in Hereford cattle.

Kohli, Cook and Dawson (1952) obtained heritability estimates for the days to final weight, efficiency and daily gain of 12.8, 0, and 13.6 percent, respectively, in 157 Milking Shorthorn steers and 3.6, 25.6 and 63.0 percent, respectively, in 62 Milking Shorthorn steers. These are quite different from the results obtained in this study. The estimates they obtained were based on the error variance within sire, ration and year for the 157 steers, but based on the error variance within sires without removing year variance for the 62 steers for efficiency and days to final weight because variance due to years was not significant for these characters. Since the ration directly influenced the growth characters and would interfere with the estimation of the hereditary part of the characters in the 157 steers, it was decided to use the smaller group of steers in this study. The estimates for the 62 steers fed with the same ration, if based on the error variance within sires and years, would be 80.0, 17.2 and 63.0 percent, respectively. These are higher than the estimates in this study simply due to the removal of the four single steer sub-groups which increased the variation between sire sub-groups.

The heritability estimates for the three beef characters were high and close to each other. They were 58.3, 66.7 and 69.1 percent for slaughter grade, carcass grade and dressing percentage, respectively. Knapp *et al.* (1946a, 1950) obtained a heritability of 63 and 45 percent for slaughter grade, 84 and 33 percent for carcass grade and only 1 percent for dressing percentage in Hereford cattle. The breed difference might be one of the main reasons causing the difference in heritability of the three beef characters. The technique of scoring the steers and carcasses and the treatment of the carcasses might be other reasons for these differences. The estimates in this study indicate that there are good prospects for the improvement of these three beef characters with the selection of better sires and dams.

The mean squares and heritability estimates for the nineteen body measurements are listed in table 2. Six of the measurements had significant year variances, two had significant sire variances. All the nineteen measurements were divided into six groups. The measurements in each group tend to be closely related as described by Yao, Dawson and Cook (1953). The heritability estimates for some of the measurements in these groups show indications of being closely related. The heritability estimates for the height measurements range from 4.6 to 65.5 percent. The height at withers is the highest and the height at flank is the lowest in heritability. Gowen (1933) obtained a heritability

estimate of 52 percent for the height at withers and 59 percent for the depth at withers in Jersey cattle. Schutte (1935) obtained 76 percent for the height at withers, and 20 percent for the depth of chest for a crossbred herd. The differences might be attributed to the differences between the variability of these body measurements in different breeds.

All the three length measurements have zero heritability. However, Gowen (1933) obtained 58 percent of heritability for body length and 68 percent for rump length. Schutte (1935) obtained 48 percent for body length.

For the head measurements, the width between eyes had a heritability of 63.1 percent and the width of muzzle 50.0 percent, the second and third highest estimates for the body measurements. The length of nose had zero heritability.

All the five width measurements had low heritability estimates ranging from zero to 15.1 percent. The width at last ribs was the highest in the group and the width at shoulders was the lowest with zero heritability. The low heritability of width measurements might be indications that these measurements are controlled chiefly by the environmental conditions. Gowen (1933) obtained a heritability of 70 percent for the width at hips. Schutte (1935) obtained 64 percent for the width at thurls, and 62 percent for the width at hooks.

For the circumference measurements, only the circumference at foreflank had a heritability of 32.3 percent. The circumference at navel and the circumference at rear flank both had zero heritability. Gowen (1933) obtained a heritability of 57 percent for heart girth, and 47 percent for paunch girth. Schutte (1935) obtained 35 percent for heart girth.

The heritability for shin bone circumference was 33.5 percent.

The heritability estimates obtained in this study vary from zero to 69.1 percent. Some of the characters that seem quite similar or which have common components actually have sufficient differences so that one would not expect that they would have the same heritability. For example, both average daily gain and efficiency are expressions of the gain or growth of the animal but one is in terms of the days the animal was fed and the other is in terms of lb. total digestible nutrients consumed. Obviously heredity and environment might affect the days and the amount of total digestible nutrients differently and in this study a greater portion of the variance in lb. total digestible nutrients consumed is due to environment than is the case with the number of days the animals were fed (see figures in columns 3 and 4, table 1). For the

body measurements, depth of chest and width at chest are at the same part of the body but the heritability estimates are 40.1 and 9.4 percent, respectively. It is probable that these two characters are influenced to a different degree by such things as fatness and skeletal development at the age when the steers reach 900 lb., and that the variation of these components gives rise to the differences in the estimated inheritance of width and depth of chest. Moreover, the chest depth of an animal is less affected by the position of its body and the movement of breathing than the chest width when the animal is being measured. The three circumference measurements are similar in that the circumferences at navel and at rear flank are more variable than the circumference at foreflank. Variations of this type increase the individual error variances as shown in table 2 and may minimize or entirely overshadow the genetic influence from sires and make the heritability estimates as low as zero percent.

The small number of animals makes possible large sampling errors, thus some of the differences may be due to chance. The dams' influence which could not be studied in this paper might be another possible cause of discrepancies in the results.

All the twenty-seven characters could arbitrarily be put into four heritability groups. The characters which had a heritability higher than 40 percent could be regarded as highly hereditary and in the high heritability group. The characters with a heritability between 20 and 40 percent could be placed in the medium heritability group and 1 to 20 percent in the low heritability group. The characters with a heritability lower than 1 percent could be listed in the no-heritability group. The groups are as follows:

High heritability group: Dressing percentage 69.1 percent, carcass grade 66.7 percent, height at withers 65.5 percent, width between eyes 63.1 percent, slaughter grade 58.3 percent, days to final weight 56.6 percent, birth weight 50.6 percent, width of muzzle 50.0 percent, days to weaning 45.1 percent, depth of chest 40.1 percent.

Medium heritability group: Circumference at shin bone 33.5 percent, height at floor chest 33.4 percent, circumference at foreflank 32.3 percent.

Low heritability group: Daily gain 18.8 percent, width at last ribs 15.1 percent, width at chest 9.4 percent, height at flank 4.6 percent, width at loin 4.5 percent, efficiency 3.2 percent.

No-heritability group: Width at hip 0.5 percent, length of body

0 percent, length of rump 0 percent, length of coupling 0 percent, length of nose 0 percent, width at shoulder 0 percent, circumference at navel 0 percent, circumference at rear flank 0 percent.

Summary

Heritability estimates were obtained for five growth characters, three beef characters and nineteen body measurements from 58 Milking Shorthorn steers raised at the Agricultural Research Center, Beltsville, Maryland, from 1943 through 1949. All steers were slaughtered at a live weight of approximately 900 lb. Component variances for each character were computed and the paternal half-sib correlation method was used to estimate the heritability coefficients.

Estimates of the percent heritability of the growth characters ranged from 3.2 to 56.6 percent. Of these five growth characters, birth weight, days to weaning and days to final weight were of high heritability and showed more possibility of being improved by selection than the others. All the three beef characters, slaughter grade, carcass grade and dressing percentage, were of high heritability and the prospects for their improvement by selection appear to be good. Of the nineteen body measurements, height at withers, width between eyes, width of muzzle and depth of chest had high heritabilities of 40.1 to 65.5 percent. Height at floor chest, height at flank, circumference at foreflank, circumference at shin bone and all the width measurements except width at shoulder had heritabilities varying from 4.5 to 33.5 percent. The three length measurements, circumference measurements at navel and at rear flank, length of nose and width of shoulder had zero heritability.

All the twenty-seven characters were divided into four groups: ten characters were of high heritability (40.1–69.1 percent); three characters of medium heritability (32.3–33.5 percent); six of low heritability (3.2–18.8 percent); and eight, of no-heritability (0–0.5 percent).

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BRAHMAN-HEREFORD CROSSBREDS AND HEREFORDS—GAINS, CARCASS YIELDS AND CARCASS DIFFERENCES

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IN evaluating beef cattle for meat production, economy of gain and yield of meat must naturally receive most consideration. The value due to increased carcass yield might be offset because of low utilization of feed and higher percentage of the less desirable carcass cuts. British developed beef cattle have been selected intensively for meat production, but there are areas in the United States where the oppressive summer climate causes these animals to perform below their inherent potential. Brahmans, Africanders and their crosses excel in these areas, and this is reflected in their increased number. Rhoad (1938) showed that Brahmans and their crosses spent more time grazing during hot summer days than Angus. Ittner *et al.* (1954) made similar observations when comparing Brahman-Hereford crossbreds and Herefords. Brahman-Hereford crossbreds made greater summer gains while Herefords made greater and cheaper winter gains. Black *et al.* (1934) reported Brahman crossbred cattle yielded two to four percent higher than Herefords and Shorthorns. Carcass differences were very small in the percent yield of fore and hind quarters. The cost of feed lot gain, however, was highest for the Brahman crossbreds.

California has a large area consisting of the Imperial, Cochella, and Palo Verde Valleys where the fall, winter, and spring months are particularly suitable for feeding cattle. The summer months are quite oppressive because of the high temperatures and relative humidity. Because of these climatic conditions, breeding herds are uncommon.

The object of this report is to present information on the feed lot performance, carcass yield, and other carcass characteristics which will show more clearly the relative merits of Brahman-Hereford crossbreds and Herefords to the feeder, packer buyer, and meat grader. The feed lot period extended over 200 days during the fall, winter, and spring and was expected to show any inherent differences in gaining, finishing, and feed utilization ability when none of the animals was under environmental stress.

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TABLE 1. NUMBER AND CLASSES OF ANIMALS FEED LOT TESTED

Period in Feed Lot	Days in Feed Lot	Brahman-Hereford Crossbreds		Herefords	
		Steers	Heifers	Steers	Heifers
10/8/48–5/1/49	205	6	6	6	6
10/14/49–4/29/50	197	8	8	8	8

Procedure

In cooperation with Louis H. Rochford, manager of the Tejon Ranch, Bakersfield, California, a cross breeding experiment was organized in 1946. Mr. Rochford selected 101 head of high quality Hereford cows and segregated them in a pasture. From March to September, 1947, two Brahman and two Hereford bulls were placed with these cows. The animals involved in this study resulted from these matings. They were purchased at weaning in the fall of 1948 and transferred to the Imperial Valley Field Station where they were fed out during the fall, winter and spring when climatic conditions in that area are favorable to livestock raising.

The above plan was repeated the following year. Table 1 is a survey of the number and kinds of animals fed during the two years of experimentation. In each year feeding and management were the same.

There was no significant year difference in daily rate of gain for either breed or sex. Table 2 summarizes the combined results of the two feeding trials.

TABLE 2. A COMPARISON OF FEED LOT PERFORMANCE OF BRAHMAN-HEREFORD CROSSBREDS AND HEREFORDS

Comparison	Hereford	Brahman-Hereford
No. of Animals	28	28
Average Initial Weight	496	494
Average Daily Gain	2.16	1.90
Feed per 100 lb. Gain		
Grain	282	307
Dry Beet Pulp	173	187
Alfalfa Hay	293	325
Sudan and Barley Hay	68	77
Beet Top Silage	27	33
Total	843	929

The Herefords gained .26 lb. per day more than the crossbreds, a highly significant difference with 95 percent confidence limits of .14 and .38. The Herefords required less feed per 100 lb. gain than did the crossbreds.

The average daily gain for steers was 2.15 lb. per day and for heifers, 1.91 lb. per day. The sex difference in gain of .24 lb. per day is highly significant with 95 percent confidence limits of .12 and .36.

Dressing Percentages and Carcass Analyses

The effect of breed and sex was analyzed in a factorial design for dressing percentage (based on hot carcass weight) and various carcass cuts expressed as percentages of total carcass weight. These data were obtained from the animals in the feeding trials. Data from two of the Hereford heifers were excluded as, upon slaughter, they were found to be pregnant. The results of this analysis are set forth in table 3. It is quite noteworthy that crossbred carcasses cut out as well as Hereford carcasses and produced less flank—a cheap cut. In view of the fact that heifers develop differently than steers, the carcass differences between sex were not unexpected.

Percentage of Bone in Carcass

An estimate of percentage of bone in the carcass was made by analyzing the composition of the 11th and 12th rib cut. Data were obtained from 13 of the crossbred steers and 13 of the Hereford steers. A significant breed difference was found and is presented in table 3, but this difference is most likely a simple reflection of the higher finish of the Herefords.

For two of the crossbred steers and two of the Hereford steers, the above method of estimating percentage of bone in the carcass was compared with an estimate based on complete boning out of the carcass. The results of this comparison are presented in table 4.

On the basis of this comparison of the two methods, it appears that the analysis of the 11th and 12th rib cut underestimates the percentage of bone but does not seriously distort the estimated breed difference.

Percentages of Fat and Lean in the Carcass

The percentages of fat and lean in the carcass as estimated by the rib analyses are presented in table 3. The Hereford carcasses were fatter than the crossbred carcasses, and the difference was statistically significant at the 5 percent level of probability.

TABLE 3. BREED AND SEX COMPARISONS FOR DRESSING PERCENTAGES, CARCASS CUTS, AND PERCENTAGES OF BONE, LEAN, AND FAT IN THE CARCASS

Trait	Brahman-Hereford Crossbred	Hereford	Breed Difference: Crossbred Minus Hereford	F[1]	Steer	Heifer	Sex Difference: Steer-Heifer	F[1]
Dressing percentage	62.6	60.4	2.2 1.4, 3.0[2]	28.54	61.1	61.9	−0.8	3.62
Percentage forequarter	50.3	50.6	−0.3	.97	51.2	49.6	1.6 1.1, 2.1	35.99
Percentage brisket and shank	7.8	8.1	−0.3	3.65	8.1	7.8	0.3	3.40
Percentage plate	7.8	7.9	−0.1	.33	7.8	7.9	−0.1	.24
Percentage chuck	24.8	24.5	0.3	1.18	25.3	23.9	1.4 0.9, 1.9	30.62
Percentage rib	9.9	10.0	−0.1	.57	9.9	10.0	−0.1	1.37
Percentage flank	5.6	6.1	−0.5 −0.8, −0.2	9.79	5.4	6.3	−0.9 −.2, −0.6	30.59
Percentage sirloin tip and loin	18.8	18.8	0.0	.03	18.5	19.2	−0.7 1.0, −0.4	15.74
Percentage round	23.3	23.0	0.3	1.29	23.3	23.0	0.3	.62
Percentage bone in carcass[3]	14.7	12.6	2.1 0.6, 3.6	8.76				
Percentage lean in carcass[3]	54.8	52.3	2.5	1.45				
Percentage fat in carcass[3]	30.4	35.1	−4.7 −9.3, −0.1	4.43				

[1] Snedecor's F Test: Level of significance F.05=4.03, F.01=7.16.
[2] Upper and lower 95% confidence limits for significant differences.
[3] Not studied for heifers. Critical values for F in these cases are F.05=4.28, F.01=7.82.

TABLE 4. PERCENTAGE OF BONE IN CARCASS

Method of Estimating	Brahman-Hereford Crossbred: Animal	Brahman-Hereford Crossbred: Percentage Bone	Hereford: Animal	Hereford: Percentage Bone
11th and 12th rib analysis	#17	15.3	#34	13.7
	#33	13.5	# 9	12.2
Average		14.4		13.0
Complete boning out of carcass	#17	16.2	#34	15.6
	#33	16.3	# 9	14.7
Average		16.2		15.2

Carcass Grades

Table 5 presents a distribution of carcass grades by breed and sex.

Discussion

In the feed lot the Brahman-Hereford crossbreds were more nervous, alert, and curious than the Herefords. This has been noted by Hubbert, Jr. (1953) and Black *et al.* (1934). During the feeding period, the Herefords made approximately 54 lb. more gain and used 86 lb. less feed per 100 lb. gain. This would more than offset the increased carcass

TABLE 5. DISTRIBUTION OF CARCASS GRADES BY BREED AND SEX

	Carcass Grade			
Item	Choice	Good	Commercial	Utility
Breed				
Crossbred	0	20	7	1
Hereford	3	22	1	0
Sex				
Steer	1	19	7	1
Heifer	2	23	1	0

yields of the crossbreds in value and should make Herefords more attractive to the feeder who plans to feed during the cooler part of the year. In addition, the Herefords were higher finished and graded higher. On the other hand, the higher dressing yield of the crossbreds should justify more consideration as a killing animal from the packer buyer. Inspection of the carcasses revealed very little difference in uniformity of fat covering between the crossbreds and Herefords. Carcass analysis indicates there should be no criticism of the crossbreds because of conformation. The higher percentage of bone and lean in the crossbreds is a result mainly of their lower finish. Thus, it appears that so long as animals are well balanced as between fore and rear quarters, considerable variation in type, as expressed by leg length and conformation as expressed in body contour, shape of rump, etc., does not significantly affect yield of wholesale cuts.

Steers gained significantly more than heifers, an observation which has been reported in the literature many times. Heifers graded higher than steers mainly because they mature at a smaller size and carry

more finish when fed for the same length of time as steers. Steer carcasses produced larger percentages of forequarter and chuck and less percentage of flank and loin than heifers.

Summary

Hereford and Brahman-Hereford crossbred steers and heifers were compared as to feed lot performance, carcass yield, and other carcass characteristics. The animals were fed at the Imperial Valley Field Station during the time of the year when environmental conditions were least oppressive. Some of the findings are:

1. Herefords made significantly greater gains, (2.16 lb. per day as compared to 1.90 lb.) and used less feed per 100 lb. gain (86 lb.) than Brahman-Hereford crossbreds.

2. Brahman-Hereford crossbreds yielded significantly more carcass, 2.2 percent more than Herefords.

3. There was little or no difference in carcass cut out values between the two breeds. One significant difference was the higher percent of flank in Hereford carcasses.

4. Brahman-Hereford crossbred carcasses had more bone and less fat, principally because of less finish.

5. Herefords were higher finished and graded higher. Conformation and type also played a part in the grading.

6. Steers gained significantly more than heifers, 2.15 lb. per day as compared to 1.91 lb.

7. Heifers' carcasses produced less forequarter, chuck, and more flank and loin than did steer carcasses.

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CONCEPTION RATE AND OVARIAN FUNCTION FOLLOWING ESTRUS CONTROL BY PROGESTERONE INJECTIONS IN DAIRY CATTLE [1]

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REPORTS on previous investigations indicated that progesterone can be successfully used to influence the interval from one estrus to another. The previous research has given some information about the effect of this treatment on ovarian functions and conception rates for the treated females but it appeared desirable to extend this limited information.

If progesterone or some other hormone can be successfully used to control estrus and ovulation, it will permit the shipping of semen from long distances for artificial insemination at a definite time. The use of frozen semen should facilitate making planned matings of this sort, but expensive equipment and shipping containers are required which present some problems. The disadvantage of having show cattle in heat on the day of judging is such that the use of progesterone to control estrus for a few days may be desirable.

Experimental

The effects of daily progesterone injections beginning at various times during the estrous cycle on ovarian function and conception rate were investigated for 30 cows in the Cornell University herd. Included among these were 22 Holstein, 4 Brown Swiss, 3 Jersey, and 1 Guernsey. All the cows were purebreds in the college herd.

Only females with good genital health after a normal calving were selected for this experiment.

After one preliminary estrus the cows with a normal estrous cycle, within a range of 17 to 25 days, were selected. The next estrus was taken as the control for each cow and the progesterone was administered during the following cycle. Complete information on length of estrus,

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time of ovulation and ovarian functions is available for 25 of the 30 experimental cows. Length of the estrous cycle and the information on conception is available on the other 5 cows.

These treatments extended over a period of two years, from 1951 to 1953, and all cows have subsequently calved to provide complete information. The progesterone was dissolved in corn oil to make a concentration of 5 mg. per ml. Dosages of 50, 75 or 100 mg. of progesterone were injected daily subcutaneously in the neck region. In 15 cases the treatment was started on the 15th day of the cycle; in 4 cases treatment was started earlier than the 15th day; in the remaining 11 cases treatment was started on the 17th, 18th and 19th day of the cycle. In 21 cows the period of treatment for the progesterone injections was 7 days; 5 cows were treated for 3 days; 2 were treated for 9 days, and 2 for 13 days.

The dosages and time of administration in the estrous cycle were based on information presented by Dutt and Casida (1948), Christian and Casida (1948), O'Mary, Pope and Casida (1950), Raeside and Turner (1950), Ulberg, Christian and Casida (1951), Ulberg, Grummer and Casida (1951) and Willet (1950).

The length of estrus was determined by checking the cows with a young bull at 4-hour intervals at the time of expected estrus. When they appeared to be approaching estrus the time interval for checking was reduced to 2 hours. End of estrus was checked at 2-hour intervals. Cows were considered to be in estrus if they stood when mounted and out of estrus when they would no longer stand. The time of ovulation was determined by rectal palpation every 2 hours following the termination of estrus. Ovarian changes and follicle developments were determined by daily examinations a day or two before the start and during the experimental period. Each cow was limited to one experimental period and the breeding was by natural service to bulls with high fertility. The ovaries were examined on the 5th, 14th and 20th day following estrus to determine the condition of the ovary, the size of the corpus luteum and whether cysts were present.

Results and Discussion

During the control period the 30 cows averaged 20.8 days for their estrual cycle. The range was from 18 to 24 with one each at the extreme, 2 at 19, 14 at 20, 4 at 21, 5 at 22, and 3 at 23 days from one estrus to another.

For the experimental period the 30 cows averaged 26 days for their

estrual cycle and estrus occurred an average of 4.6 days after treatment with progesterone ceased. There were 3 cows in estrus 3 days after treatment was stopped, 15 on the 4th day, 8 on the 5th, and 1 each on the 6th, 7th, and 9th day. Four of these 30 estrous periods were silent, *i.e.* ovulation occurred without estrus. These were on the 5th day for 2 cows, and 1 each on the 7th and 9th day after treatment ceased. The reproductive performance for each cow is given in table 1.

Since 15, or half, of the treated cows were in estrus on the 4th day after the progesterone treatments were stopped compared to 14 cows with an estrous cycle of 20 days during the control period, the chances of accurately predicting estrus on a given day are about equal in both periods, but progesterone treatment does provide an opportunity for shifting the time of estrus.

Christian and Casida (1948) reported that yearling heifers came into estrus 5–6 days after end of treatment. Ulberg, Christian and Casida (1951) found the interval from the time when injections ceased to beginning of heat in heifers decreased from 5.2 days as the dosage level was decreased. Willet (1950) found that on the average estrus followed 5 days after treatment ceased but ranged from 4 to 7 days.

A complete ovarian examination at daily intervals before and after estrus was made for all 30 cows, but the length of estrus and the examinations at 2-hour intervals during estrus was made for only 25 of the 30 cows during the control and experimental periods. The normal results during the control period showed an average length for estrus of 19.3 hours and an ovulation time of 10.4 hours after end of estrus, or 29.7 hours from the start of estrus. No ovarian abnormalities were detected before, during, or after estrus for the control period.

During the experimental period, 14 of the 25 cows examined had normal estrous periods, 4 cows ovulated without coming in estrus, and 7 had a marked disturbance of either the length of estrus, or the time required for ovulation. The 14 cows with a normal estrus and ovulation following progesterone treatment averaged 18.6 hours for length of estrus, 10.8 hours for ovulation from end of estrus, or 29.4 hours from the start of estrus. These compared very closely with the averages for the 25 cows during the normal control period and with the average for these 14 cows during the control period which were 18.7, 10.5, and 29.2 hours, respectively.

The abnormal ovarian functions in 4 cows consisted of an unusually long estrus. These were 33, 36.5, 40, and 52 hours in length. These abnormally long estrous periods were followed with 6, 4.5, 9, and 13 hours,

TABLE 1. REPRODUCTIVE PERFORMANCE OF 30 DAIRY COWS DURING THE CONTROL AND PROGESTERONE TREATED EXPERIMENTAL PERIODS

	Control Estrus				Progesterone Treatment and Estrus												
			Ovulated		Progesterone Treatment			Estrus Started After Treat-	Total Time from Pre-		Ovulated					Addi-	
Cow No.	Length of Cycle	Length of Estrus	After End of Estrus	After Start of Estrus	Day Started After Estrus	Daily Injection	Days Treated	ment	vious Estrus	Length of Estrus	After End of Estrus	After Start of Estrus	Bred	Con- ceived	Follow- ing Estrus	tional Services Re- quired	Remarks
	days	hrs.	hrs.	hrs.	no.	mg.	no.	days	days	hrs.	hrs.	hrs.			days	no.	
1	20	16	12	28	15	50	7	4	25	27	6	33	Yes	No	20	1	
2	20	15	8	23	15	50	7	4	25	15	12	27	Yes	No	22	2	b
3	18	15	14	29	15	50	7	(Silent) (9)	(30)	(Silent)	..	..	Yes	No	18	1	b
4	21	20	9	29	15	50	7	5	26	19	12	31	Yes	No	16	1	b, h
5	20	29	10	39	15	50	7	(Silent) (5)	26	(Silent)	..	..	No	..	23	1	b, c
6	20	24	12	36	15	50	7	4	25	17	3	20	Yes	No	19	2	b, c
7	20	20	9	29	15	50	7	5	26	15	8	23	Yes	Yes	..	..	b, c
8	20	20	11	31	15	50	7	4	25	*33*	*6*	*39*	Yes	No	20	Sold	a, b, c
9	21	24	9	33	15	50	7	4	25	*52*	*13*	*65*	Yes	Yes	..	..	a
10	24	11	11	22	15	50	7	5	26	13	9	22	Yes	No	22	1	b, c
11	20	16	6	22	15	50	7	3	24	*17*	*65*	*82*	Yes	No	23	2	a, c
12	22	28	10	38	15	100	7	4	25	*13.5*	*(8 days)*	*(8.5 days)*	Yes	No	27	1	a
13	19	18	11	29	15	100	7	3	24	15	14	29	Yes	No	21	1	b
14	22	24	6	30	15	100	7	3	24	17	13	30	Yes	No	(4)	1	h
15	20	19	9	28	15	75	7	(Silent) (5)	26	(Silent)	..	..	No	..	(12)	1	g
16	23	18	14	32	7	50	13	6	25	23	10	33	Yes	Yes	..	..	c
17	21	28	6	34	9	50	13	4	25	13	11	24	Yes	No	20	1	b
18	20	14	15	29	11	50	9	4	23	*26*	*56*	*82*	Yes	No	(2)	1	a, c, h
19	20	15	7	22	11	50	9	(Silent) (7)	26	(Silent)	..	..	No	..	15	2	b
20	23	18	14	32	19	100	3	4	25	29	15	44	Yes	No	21	1	b
21	20	18	12	30	17	75	7	8	31	13	14	27	Yes	No	19	3	
22	20	20	11	31	19	75	3	4	25	*40*	*9*	*49*	Yes	No	(11)	Sold	a, b, d, h, e
23	21	21	10	31	19	50	3	4	25	*36.5*	*4.5*	*41*	Yes	No	20	1	a, b, d
24	22	16	13.5	29.5	19	50	3	4	25	29	9	38	Yes	No	21	1	
25	22	16	10	26	18	50	7	5	29	15	15	30	No	..	22	2	b
26	20	..	..	..	18	50	7	4	28	..	..	..	No	..	21	Sold	
27	19	..	..	..	18	50	7	5	29	..	..	..	Yes	No	20	3	d
28	22	..	..	..	18	50	3	5	25	..	..	..	Yes	No	23	4	f
29	20	..	..	..	19	50	7	4	29	..	..	..	Yes	No	26	1	b, d
30	23	..	..	..	19	50	7	4	29	..	..	..	No	..	..	Sold	
No.	30	25	25	25	..	..	..	30	30	21	20	20	24	3	25	23	
Av.	20.8	19.3	10.4	29.7				4.6	26.0	22.8	15.0	38.2		(12.5%)	19.0	1.52	
No.		14	14	14						14	14	14			21		
Av.		18.7	10.5	29.2						18.6	10.8	29.4					

a. Italic figures are abnormally long for length of estrus or ovulation time. b. Early follicle development. c. Very large corpus luteum. d. Cystic corpus luteum. e. Corpus luteum dislodged when large cyst ruptured. f. Metestrual bleeding occurred before follicle ruptured. Ovaries remained smooth and no corpus luteum developed before estrus 23 days later. g. Recycled by removing a normal corpus luteum to breed for freshening at show time next year. h. Two or multiple follicles.

respectively, for the time interval from end of estrus to ovulation. Disturbed ovarian function for ovulation following a normal estrus was observed in 3 cows. The time from end of estrus to ovulation was 56 and 65 hours for 2 cows and 8 days for the other individual.

The daily examination of the ovaries previous to estrus showed that frequently some follicular development occurred previous to the expected time during the period of treatment. Among the 30 cows there was a total of 16 which showed early follicular development which did not entirely follow the normal pattern. Twelve of these follicles appeared within 3 days after the injections started. Since these usually appeared on the second and third day after the treatments started, it appeared that the initial progesterone injection produced some stimulation. Hansel and Trimberger (1952) have shown that small amounts of progesterone given at the beginning of estrus will hasten ovulation in heifers, and Dutt (1953) has confirmed this for ovulation in the ewe.

The follicles which appeared previous to the expected time during treatment followed one of three avenues: seven persisted, 4 receded and enlarged later, and 5 receded and a new follicle developed. In the latter there were 3 cows which changed to the opposite ovary. Ulberg, Christian and Casida (1951) found that in order to inhibit most of the follicular development the treatment must be started early in the cycle (15th day).

During the period of progesterone treatment a considerable number of the cows discharged mucus at the time of expected normal estrus, and there was an additional increase in the size of follicles already present. If the follicle was not present, it frequently appeared at this time but these were not included among the number with early follicle development discussed above.

Ulberg, Grummer and Casida (1951) investigated the effects of four daily dosages (12.5, 25, 50 and 100 mg.) of progesterone when injected into gilts weighing 175 to 250 lb. starting on the 15th day of the estrual cycle. The 12.5 mg. dosage had little effect on retarding either heat or ovulation. The 25 mg. dosage produced variable results while a high percentage of the ovaries in gilts receiving 50 mg. daily became cystic but did not cause visible signs of heat. The 100 mg. daily injections resulted in uniform and complete post-treatment ovulation for all follicles after heat and ovulation had been prevented during the treatment interval. Two groups in which treatment started on the 19th day of the estrous cycle indicated that the treatment, to be effective, must be started at least 24 hours before the animal is to come into heat.

Tests for estrus and ovary examination during estrus showed 4 cows with silent periods, 4 with unusually long estrus, and 3 cows with abnormal time of ovulation as previously described. In addition, there were 3 cows with 2 or more follicles each. Among the 5 cows for which length of estrus and ovulation time was not available, there was 1 cow in which metestrous bleeding occurred before the follicle ruptured. Ovulation is apparently not always a prerequisite to metestrous bleeding as previous work (Hansel and Asdell, 1952) has shown. In this cow the ovaries remained smooth and no palpable corpus luteum developed before the next estrus 23 days later. There were a number of cows which had unusually large follicles during the estrus following progesterone treatment.

Examination of the ovaries following the control period showed normal corpora lutea in all 30 cows, but after the estrus following the experimental progesterone treatment there were 15 normal and 15 abnormal ovarian conditions. The abnormal included 8 abnormally large corpora lutea, 4 with very large cystic corpora lutea, 1 with metestrous bleeding without ovulation followed by smooth ovaries, and 2 cows with multiple follicles which returned for service 2 and 4 days later and conceived from the service during the second estrus. Several of the ovarian cysts were extremely large. One about the size of a hen's egg ruptured during examination, dislodged the corpus luteum and the cow returned in estrus.

The treatment with progesterone adversely affected conception rate and only 3 cows conceived from the first service among the 24 cows bred by natural service to bulls with good breeding records. This conception rate of 12.5 percent was extremely low when compared to 64 percent which prevailed for the bulls and females in the Cornell herd during the time the experiment was in progress. These differences were found to be statistically highly significant by the chi-square test.

O'Mary, Pope and Casida (1950) reported the same fertility (78.9 percent) in ewes treated with progesterone when compared to a control group (80.0 percent) as indicated by lambing. Willet (1950) obtained 11 pregnancies from 22 services to yearling heifers during the estrus following progesterone treatment. However, Baker, Ulberg, Grummer and Casida (1954) reported nearly complete infertility in gilts in which estrus and ovulation were retarded by daily 25 and 100 mg. doses of progesterone begun on either the 10th or 15th day of the cycle. Brock and Rowson (1952) noted ovum degeneration in cows in which the occurrence of estrus and ovulation was delayed for more than 5 days

after the injection of pregnant mare serum. Rowson (1951) has stated that the ova travel down the oviduct at a greatly increased rate in the presence of an active corpus luteum or after injections of progesterone. Either ovum degeneration or too rapid passage of the ova through the oviducts may be involved in the low conception rate in this experiment.

The cycles following the one after progesterone treatment appeared to be of normal length, with 80 percent of the cows showing estrus between the 19th and 23rd day from the preceding estrus. However, the cycles were not as definitely grouped for a particular day as they were for the control and the estrus following progesterone treatment.

The low conception rate experienced from the first service during the estrus following progesterone treatment did not carry over to the next estrus. When 23 of the cows were bred on second estrus following treatment, 15 conceived on this service, 5 on the second, 2 on the third, and 1 on the fourth additional service. Among these were 21 cows which had an unsuccessful service during the experimental period and 13 of the 15 cows which had abnormal ovarian conditions following treatment. Four cows were not rebred before they were sold for reasons of normal herd management. The percentage for the conception rate of the 23 cows at each additional service was 65.2, 21.7, 8.7, and 4.4 percent, respectively. This was a normal rate of conception indicating that the low fertility following progesterone treatment was temporary and was limited to the estrus following treatment.

By altering the time of starting injections in the estrual cycle, changing the dosage or the length of time of treatment, future experiments may eventually reveal combinations at which conception rates will be considerably higher than the low rate experienced in this experiment.

Summary

The effects of daily progesterone injections on ovarian function and conception rate in dairy cattle were investigated with 30 cows. Dosages used were either 50, 75, or 100 mg. daily and the injections were started at varying intervals in the estrous cycle but predominantly on the 15th day.

The interval from one estrus to another was successfully controlled. The cows came into estrus an average of 4.6 days after treatment ceased. The estrous cycle for the control period was 20.8 days compared to 26 days for the experimental period. Progesterone treatments provided an opportunity for shifting the time of estrus, but had no advantage in predicting estrus on a particular day.

No ovarian abnormalities were detected before, during or after estrus for the 30 cows during the control period. However, during the experimental period, 16 of these cows had early follicular development. Following estrus the corpus luteum was normal for all 30 cows during the control period, but after the experimental period 15 cows had abnormal ovarian conditions involving luteal development.

The length of estrus and the time of ovulation were available for 25 cows. During the control period the average length of estrus was 19.3 hours and ovulation time averaged 10.4 hours after the end of estrus.

During the experimental period only 14 cows had estrous periods of normal length, 4 had a silent estrus (ovulation without estrus), and 7 had a marked disturbance of either the length of estrus or ovulation time. A number of cows had unusually large follicles during the estrus following progesterone treatment.

The treatments with progesterone provided a marked influence on conception. Only 3 cows, or 12.5 percent, conceived from the first service for 24 cows bred by natural service to bulls with high fertility. The estrus following the one after the progesterone treatment had a normal cycle length from the previous estrus and normal conception rates were indicated with a 65.2 percent conception among the 23 cows bred. This indicated that the low fertility following progesterone treatment was temporary and was limited to the estrus following treatment.

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A STUDY OF THE RELATION BETWEEN BODY CONFORMATION AND CARCASS QUALITY IN FAT CALVES [1]

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VARIATION in body form or conformation is of interest to students of theoretical and applied biology. Genetic improvement of beef cattle has been largely contingent upon the use of conformation as a selection criterion. Ideals or standards of conformation were originally established because it was thought they were indicators of desirable production and carcass traits. Many animal husbandmen have assumed a perfect correlation between certain points of conformation and merit in corresponding production and carcass characteristics. Relative economic value is frequently determined accordingly.

Two problems of interest to the animal breeder arise from this situation. There is no practical, objective, quantitative method of measuring conformation. It is evaluated on the basis of some form of visual appraisal. Further, valid experimental evidence indicating a high relation between conformation score and production and carcass traits is lacking. Indeed, the finding of Knapp and Clark (1951) that score at weaning is not an index of subsequent gains in the feed lot indicates that such relations may not exist.

A number of investigators have made use of body measurements in attempting to devise quantitative measures of conformation. A review of the literature [see Yao, Dawson and Cook (1953), Durham and Knox (1953), Cook, Kohli and Dawson (1951), Kohli, Cook and Dawson (1951), Mason (1951)] does not lend great support to the use of live animal measurements as quantitative indicators of conformation or production and carcass traits. This may be due to the fact that investigators of beef form have considered conformation as a static characteristic. Variation in conformation between individual animals within a species is due to differences in the relative proportions of the various parts to each other and to the animal as a whole. Conformation

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[2] Department of Animal Husbandry, Reno, Nevada. The author is indebted to the Nevada Junior Livestock Show Board and the 4-H and Future Farmer exhibitors for making the animals available and assisting with the measurements.

at any stage of development is the result of differential growth rates of the various dimensions. Studies of form should take account of the dynamic processes of growth. Lerner (1939) pointed out that attention should be centered on the processes leading to the assumption of the specific form, rather than the end products themselves and suggested the allometric equation as a means of accomplishing this.

Kidwell *et al.* (1952) concluded that the allometric equation afforded a quantitative description of beef cattle conformation and that conformation might be changed in a specific manner by selecting for appropriate values of the parameters. Practical application awaits knowledge of the relative proportions of the desired form. There may be many desired forms and the desirability of any particular form may vary in time or according to circumstance. Within these limitations however, it may be possible to establish the relative proportions of a particular desirable form.

The purpose of this investigation was to determine if conformation of fat calves may be quantitatively described by the relation among several body measurements and evaluated by the relation between several body measurements and desirability as determined by slaughter grade, carcass grade and dressing percent.

Materials and Methods

The animals used in this study consisted of 64 Hereford steer calves exhibited at the 1954 Nevada Junior Livestock Show. The calves varied in age from 10 to 16 months, and had been fed from 180 to 240 days. They might be considered as a selected group of weanling calves prior to feeding. It is necessary to restrict generalization of results accordingly.

Body measurements were taken on arrival, and included weight, height at withers, height at hooks (tuber coxae), heart girth (*i.e.* chest girth), round (distance from patella to patella parallel to the ground), length of body (horizontal distance from the point of the shoulder to the intersection with a line falling vertically from the posterior point of the tuber ischii), length of head (top of poll to tip of muzzle), width of head (at the zygomatic arch), width of hook bones (distance between the tuber coxae), width and depth of chest. Weight was taken on a uniform shrink to the nearest two and one-half lb. Heart girth, length of body and round were measured to the nearest 0.1 inch with a corded linen tape. The remaining measurements were taken to the nearest 0.1 inch with calipers especially designed for the purpose.

The steers were assigned a live grade by a committee of judges and

a corresponding numerical grade as follows: Low prime—94, top choice—91, choice—88, low choice—85, top good—82, etc. Dressing percent was calculated on the bases of shrunk live weight and chilled carcass weight. Carcass grades were assigned in the same manner by a U.S.D.A. grader.

Correlation and regression methods described by Snedecor (1946) were used in the analyses of the data.

TABLE 1. MEAN, STANDARD DEVIATION AND COEFFICIENT OF VARIATION OF THE MEASUREMENTS

Item	Mean	Standard Error	Coefficient Variation
			Percent
Weight	843.16	41.93	39.8
Ht. withers	43.90	0.20	3.6
Ht. hooks	45.40	0.20	3.6
Chest depth	23.90	0.13	4.4
Chest width	17.60	0.15	6.9
Head Length	17.05	0.08	3.7
Head width	8.49	0.04	3.3
Width hooks	17.89	0.14	6.5
Heart girth	69.10	0.46	5.3
Round	36.85	0.31	6.7
Length	58.64	0.40	5.4
Live grade	87.77	0.51	4.6
Carcass grade	84.85	0.82	7.5
Dressing percent	60.96	0.34	4.3

Results and Discussion

The mean, standard error and coefficient of variation of the measurements are presented in table 1. These values are in general agreement with those reported in the literature. It will be noted that the coefficient of variation for body weight is relatively high.

Zero order correlations between the various measurements and the carcass traits are presented in table 2. Many of these correlations are of the type Pearson (Snedecor 1946, p. 162) termed "spurious" because of their relation to general size, and must be interpreted accordingly.

Weight has a fairly high positive correlation with all other body measurements except round. The high correlation between weight and heart girth and the much lower coefficient of variation of heart girth leads to the conclusion that heart girth provides a more suitable measure of total size than weight for studies of growth and form. The observed

large correlations between weight and the carcass traits would be expected if heavier calves also carried a higher degree of finish.

The high correlation between height at withers and height at hooks

TABLE 2. CORRELATIONS BETWEEN BODY MEASUREMENTS AND CARCASS TRAITS

	Weight	Ht. Withers	Ht. Hooks	Chest Depth	Chest Width	Head Length	Head Width	Width Hooks	Heart Girth	Round	Body Length	Slaughter Grade	Carcass Grade
Ht. withers	.628**												
Ht. hooks	.642**	.927**											
Chest depth	.808**	.621**	.600**										
Chest width	.751**	.296*	.319**	.470**									
Head length	.667**	.623**	.576**	.554**	.491**								
Head width	.608**	.300*	.275*	.540**	.502**	.410**							
Width hooks	.821**	.336**	.324**	.663**	.726**	.497**	.488**						
Heart girth	.896**	.491**	.476**	.799**	.804**	.599**	.578**	.831**					
Round	.199	.342**	.267*	.199	.058	.298*	.302*	.125	.156				
Body length	.580**	.527**	.593**	.522**	.333**	.421**	.266*	.394**	.466**	.676**			
Slaughter grade	.481**	.109	.099	.294*	.556**	.329**	.382**	.457**	.509**	.052	.076		
Carcass grade	.617**	.104	.131	.382**	.720**	.218	.414**	.628**	.694**	—.102	.282*	.603**	
Dressing percent	.578**	.319*	.332**	.394**	.651**	.401**	.358**	.526**	.634**	—.136	.351**	.652**	.714**

* Significant at the 5% level.
** Significant at the 1% level.

indicates that for most purposes only one or the other is sufficient. This is in agreement with the findings of Lush (1928) and Yao *et al.* (1953). The relation of height at withers to measures of length and depth is fairly high, but the relation of height to width measures is low.

The insignificant correlation of height at withers with slaughter and carcass grade and its low but significant positive correlation with dressing percent is at variance with the results of Cook *et al.* (1951). This may reflect a greater influence of finish in these data. The steers studied by Cook *et al.* were all slaughtered at 900 lb. live weight, while those used in this study varied from 655 to 1165 lb. Correlations involving height at hooks are similar to those for height at withers.

The relations involving chest width are generally higher than those involving chest depth. This is particularly true of the correlations with the carcass traits. The high correlations of chest width with carcass traits observed in these data are contrary to those observed by Yao et al. (1953). The fact that their animals were measured at a uniform weight as compared to the varying weights of these does not offer a satisfactory explanation. The partial correlations with heart girth constant (table 4), are highly significant.

Head measurements were studied because many animal husbandmen attach great significance to head form. The total correlations of head measurements with carcass traits would indicate a small positive association. Further analyses (tables 3 and 4) indicate the observed correlations are a reflection of general size. This is in agreement with the findings of Lush (1928).

Correlations involving width of hooks are smaller but similar to those for chest width. Heart girth is fairly highly associated with all other body measurements except round, and with all carcass traits in a positive manner. This further supports the use of heart girth as a measure of total size. Body length is not highly associated with the other measures or carcass traits.

The relations involving round are small or insignificant. No exact explanation is immediately apparent. It is possible that the measure of round employed was not accurate or that it does not indicate the true development of the round. With respect to the carcass traits, it is possible that round is little associated with merit. The carcass traits are highly correlated. This is in agreement with the findings of Yao *et al.*

An important objective of the study was to evaluate the relation between relative proportions and desirability as measured by the three carcass traits. Heart girth was selected as the most suitable measure

TABLE 3. CORRELATIONS BETWEEN RATIOS AND CARCASS TRAITS

Ratios	Ht. Withers	Body Length	Width Hooks	Width Chest	R.M. × 100	Head Length
Traits	Heart Girth X_1	Heart Girth X_2	Heart Girth	Heart Girth	Ht. Withers	Head Width
Live grade	−.551**	−.440**	.039	.241	−.027	−.067
Carcass grade	−.677**	−.347**	.081	.284*	−.148	−.136
Dressing percent	−.441**	−.231	−.047	.257*	.313*	.074

* 5 percent level of significance.
** 1 percent level of significance.

of total size. Height at withers, body length and width at hooks were selected to represent height, length and width respectively. The ratio of each to heart girth was computed. Gregory (1933) suggested the ratio (round × 100)/(height at withers) as an index of muscling. Guilbert and Gregory (1952) reported the ratio to be highly correlated with grade, although no correlation coefficient was cited. The ratio was computed from the data used in this study.

Since it is generally agreed that it is the relative proportions or shape rather than actual size that is of importance in evaluating the head, the ratio of head length to head width was calculated.

The correlations between these ratios and the three carcass traits are presented in table 3. The ratio of height at withers to heart girth shows a fairly large negative correlation with all three carcass traits. This indicates that the lower the animal, relative to heart girth, the greater the carcass merit.

The ratio of body length to heart girth exhibits a low but highly significant negative relation with slaughter and carcass grade, but an insignificant correlation with dressing percent. This indicates that the shorter the animal, relative to heart girth, the greater the carcass merit.

TABLE 4. PARTIAL CORRELATIONS WITH HEART GIRTH CONSTANT

	Ht. Withers	Ht. Hooks	Chest Depth	Chest Width	Head Length	Head Width	Width Hooks	Body Length	Live Grade	Dressing Percent
Live grade	....	....	−.218	.287*	.035	.088	.034	....	....	....
Carcass grade	....	....	−.397**	.378**	....	.022	.127	−.064	.403**	.492**
Dressing percent	.012	.044	−.243	.307*	.034	−.014	−.002	.082	.494**	....

* 5 percent level of significance.
** 1 percent level of significance.

The ratio of width of hooks to heart girth was not at all associated with the carcass traits. Since width of hooks is largely a skeletal measure, while width of chest also reflects finish, the correlation between the carcass traits and the ratio of width of chest to heart girth was computed. The relations involving carcass grade and dressing percent were low but positive and significant. It would seem that relative width is of little importance in determining carcass quality, although actual width, independent of size, is of importance.

The ratio of (round $\times 100$)/(height at withers) was not significantly associated with slaughter or carcass grade, but there was a low significant negative correlation with dressing percent. The reason for the discrepancy between these results and those cited is not apparent. The fact that Guilbert and Gregory worked with breeding cattle as compared to the fat calves of this study may be relevant.

The ratio of head length to head width is not at all correlated with the carcass traits. This suggests that the zero order correlations observed with head width and length are a reflection of general size.

In order to gain further information as to the influence of general size on the total correlations, partial correlations with heart girth constant were calculated between certain measures and the carcass traits. These are presented in table 4. Partial correlations were not calculated in those instances where total correlations were insignificant. It seems reasonable to conclude that chest width exerts an important influence on carcass traits independent of total size. This is also true of the correlations among the carcass traits.

The partial correlation between chest depth and carcass grade is of special interest. The positive value of the total and the negative value of the partial correlation indicates two opposed forces. On the one hand, the larger the animal, the deeper the chest and the higher the grade. On the other hand, if size be held constant, the shallower the chest, the higher the grade. Although contrary to long established belief, this seems reasonable in that there would be relatively less of lower priced carcass cuts. These conclusions are in agreement with those of Green (1954).

In general, the partial correlations indicate that the total correlations observed between carcass traits and height at withers, height at hooks, width of hooks, head length and width, body length and chest depth, except with carcass grade, are only a reflection of total size. They are, therefore, spurious in the sense defined by Pearson.

These analyses lead to the conclusion that neither head length nor

width, nor the ratio of length to width is associated with carcass merit. It would appear that if head form is associated with carcass merit, except in a spurious fashion, the relation is not indicated by the carcass traits studied or the important aspects of head shape are not reflected in the measures that were analyzed. It is possible that both play a role, or that head form *per se* is not associated with carcass merit.

Inspection of the zero order and partial correlations indicated that the most important measures indicating carcass quality are: Height at withers/heart girth, length/heart girth and width of chest. They may be designated X_1, X_2 and X_3 respectively, and slaughter grade, carcass grade and dressing percent designated Y_1, Y_2 and Y_3 respectively. Multiple regression equations and associated multiple correlations are:

$$Y_1 = 91.21 - 0.584\ X_1 + 0.149\ X_2 + 1.224\ X_3 \quad R = .592^{**}$$
$$Y_2 = 82.37 - 0.999\ X_1 + 0.200\ X_2 + 2.831\ X_3 \quad R = .721^{**}$$
$$Y_3 = 38.08 - 0.026\ X_1 - 0.014\ X_2 + 1.490\ X_3 \quad R = .652^{**}$$

The multiple correlation was little different from the zero order correlation with chest width for all three carcass traits. It appears that chest width alone provides nearly as much information concerning carcass quality as the multiple regression. The simple regression of carcass trait on chest width would be almost as accurate as the multiple regression for purposes of estimation.

Yao *et al.* (1953) suggested indices for carcass traits on the basis of observed relations between beef traits and correlated body measurements. The indices apparently were derived by empirical rather than biological, mathematical or statistical methods, and were not demonstrated with actual data. Since the zero order correlations involving chest width observed in these data are higher than the multiple correlations reported by Yao *et al.*, it is doubtful that the indices they suggested would be applicable in this instance.

It would appear that much of the relation observed between various body measurements, and between measurements and carcass traits are due to their relation to total size. The ratios of height at withers to heart girth, and body length to heart girth and the linear measure of chest width are related to the carcass traits studied, independent of total size. However, little is gained by considering more than chest width.

Desirable proportions are low at withers, short of body, and shallow of chest relative to heart girth, but wide at the chest irrespective of

total size. These are essentially in agreement with the proportions described by Lush (1932).

These data support the conclusion of Lush that steers of widely different form may have equal carcass value and dressing percent and vice versa. However, the observed relations are sufficiently high to indicate that a change toward the proportions described would result in a corresponding change in the carcass traits studied. Estimates of heritability of the parameters of the allometric equation relating height at withers and body length to heart girth (Kidwell *et al.*, loc. cit.) indicate that mass selection would be effective.

There are two obvious and important limitations of the present data: (1) It was not possible to identify the genetic and environmental components of the relations studied; (2) The measures of carcass merit are not sufficiently comprehensive. Carcass quality might better be described in terms of the wholesale cuts weighted according to relative economic value.

Summary and Conclusions

Data from 64 fat Hereford steer calves were used to study the relations among eleven body measurements and three carcass traits.

Heart girth appears to be the most satisfactory single measure of total size for studies of growth and form.

Relations among the various body measurements were studied. In general, the analysis indicated that much of the observed correlation among the various measures arises from their relation to general size. This appears also to be true for the relations between the measurements and carcass traits, with the exception of width of chest.

The relation between several ratios and the carcass traits were studied. These data indicate that the most important measures influencing carcass quality are: chest width, and the ratio of height at withers to heart girth, and length to heart girth. A multiple regression analysis indicated that chest width alone provides nearly as much information concerning carcass quality as does a multiple regression including the two ratios.

The most desirable proportions are low at the withers, short of body and shallow of chest, relative to heart girth, but wide of the chest, irrespective of size. Selection on the basis of appropriate values of the parameters of the allometric equation should lead to positive results. It is noted that these data were taken from a partially selected group

of fat calves. The results and conclusions should be interpreted accordingly.

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THE EFFECT OF ANTIBIOTICS [1] UPON THE DIGESTION OF FEED NUTRIENTS BY YEARLING STEERS, WITH BACTERIOLOGICAL DATA [2]

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ALTHOUGH the action of several of the antibiotics upon domestic animals has been determined and more or less satisfactorily explained, tests made with ruminants have been too few to permit an appraisal of the value of such drugs for beef cattle. Work reported by Bell *et al.* (1951) indicated that aureomycin (0.2–0.6 gm., daily) had severe physiological effects on beef steers and caused a decrease in digestibility of feed nutrients. Neumann *et al.* (1951) found little difference between daily gains of heifers fed aureomycin or aureomycin and vitamin B_{12}, and those fed the basal ration alone. Perry *et al.* (1954) reported increased gains for calves and yearlings fed 75 mg. aureomycin daily.

The purpose of the trials with beef steers reported in this paper was to study the effect of feeding antibiotics upon the digestion of feed nutrients and upon the microflora of the rumen, and to observe physiological changes which result from feeding different antibiotics at varying levels.

Experimental

Series A

Five yearling Hereford steers averaging 658 lb. in weight were used in this series of tests. Each steer was fed a daily basal ration of 6 lb. chopped red clover hay, 8 lb. corn-and-cob meal, and 0.5 lb. of soybean oil meal during an 18-day preliminary and 7-day collection period constituting Trial I.

After the last collection in Trial I, the basal ration was reduced to 11.5 lb. per head daily, since three steers failed to consume the entire ration. The proportion of feed constituents in the ration was not

[1] Aureomycin furnished through the courtesy of Lederle Laboratories Division, American Cyanamid Company, Pearl River, New York, and the penicillin supplied through the courtesy of Merck and Company, Inc., Rahway, New Jersey.

[2] Published with the approval of the Illinois Agricultural Experiment Station.

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changed. After 7 days on this new level of feeding each steer was fed a mixture of 100 mg. of streptomycin sulphate, 100 mg. of crystalline aureomycin hydrochloride, 100 mg. of terramycin, and 30 gm. of sulfathalidine powder, mixed in the ration. This dosage which was repeated at 36 and 72 hours produced no visible physiological change. Nine days after the last dosage of drugs was given feces were collected for a period of 7 days constituting Trial II.

At the end of Trial II the steers were continued on the basal ration for 3 weeks. They were then started on 100 mg. of crystalline procaine penicillin G per head daily. This level of the drug was fed during a 2-week preliminary and a 7-day collection period constituting Trial III.

At the end of Trial III, the steers were left on penicillin in an attempt to ascertain tolerable levels. Two steers remained on the 100 mg. level while the dosage for each of the other three was increased to 200 mg. per day. At the end of 4 days the dosage was increased to 400 mg. for two of these steers and at the end of the next 4 days it was increased to 800 mg. for one of them. The last day penicillin was fed, rumen samples were taken by stomach tube for bacteriological study. The steers fed 100 and 800 mg. of penicillin, along with a control steer, were slaughtered the day after rumen samples were taken.

Series B

For the trials of Series B, six yearling steers and a different basal ration were used. Nitrogen balance was determined in addition to other observations. The new ration was composed of chopped alfalfa-brome-grass hay, 5; ground corn-cobs, 5; ground corn, 5; and soybean oil meal, 1. It was fed during all trials, each steer receiving 16 lb. total feed per day.

In Trial IV all steers were fed only the basal ration during the 18-day preliminary and 7-day collection periods.

In Trial V which was started immediately after Trial IV the steers were divided into two groups. One group was fed 32 mg. and the other 100 mg. of aureomycin mixed into the basal ration over a 36-day preliminary and 7-day collection period. The aureomycin was supplied in the form of Aurofac 2A (Lederle) containing 3.6 gm. of crystalline aureomycin hydrochloride and 1.8 mg. of vitamin B_{12} per lb.

In Trail VI the steers were changed to 32 and 100 mgs. of penicillin supplied from Antibiotic Feed Supplement (Merck) containing 0.2 gm. procaine penicillin G per gm. of supplement. The supplement was

mixed with the basal ration at each feeding over a 28-day preliminary and 7-day collection period.

On the seventh day of collection in Trial VI the level of penicillin was increased to 400 mg. per head daily for all steers. Collections were continued for 4 days, constituting Trial VII, and for 3 days thereafter, constituting Trial VIII.

Rumen samples were removed by stomach tube after the steers had been on Trial V for 35 days and on Trial VI for 28 days. Studies of the rumen flora and environment which were made on the rumen

TABLE 1. AVERAGE COEFFICIENTS OF DIGESTIBILITY

Trial No.	No. of Steers	Treatment	Average Apparent Digestibility				
			Dry Matter	Crude Protein	Crude Fiber	Ether Extract	N-Free Extract
			%	%	%	%	%
		Series A					
I	4	Basal	68.0	48.6	52.4	61.2	78.0
II	5	Mixture of drugs [1]	71.8	54.7	54.3	73.9	82.5
III	5	Penicillin, 100 mg.[2]	67.9	59.8	47.7	72.4	78.4
		Series B [3]					
IV	6	Basal	67.4	66.8	54.6	70.1	74.9
V(a)	3	Aureomycin, 32 mg.	67.6	63.3	53.9	73.2	75.2
V(b)	3	" 100 mg.	65.0	58.4	50.4	73.2	73.4
VI(a)	3	Penicillin, 32 mg.	67.4	65.9	56.4	78.2	73.5
VI(b)	3	" 100 mg.	66.6	63.4	54.6	72.5	73.8
VII	6	" 400 mg.	67.9	65.5	56.2	75.0	74.6
VIII	6	" 400 mg.	67.6	66.2	55.5	75.1	74.2

[1] Trial II started 9 days after last dosage of antibiotics.
[2] Trial III. Crystalline procaine penicillin G.
[3] Series B. Penicillin as Antibiotic Feed Supplement (Merck). Aureomycin as Aurofac 2A (Lederle).

fluid included (1) pH and Eh determinations using the Beckmann pH meter with glass and platinum electrodes, respectively, (2) the breakdown of fiber in the miniature artificial rumen, (Huhtanen and Gall, 1952) and (3) the isolation of the predominant rumen bacteria, using an anaerobic cultural procedure (Huhtanen and Gall, 1952a; Huhtanen, Rogers and Gall, 1953).

Results and Discussion

Table 1 gives the coefficients of digestibility for all trials in Series A and B while table 2 gives the results of the nitrogen retention studies in Series B.

In Series A, the digestibility of all nutrients in the basal ration was

increased after feeding the mixture of antibiotics (Trial II). Penicillin alone in Trial III produced a variable response. In Series B aureomycin from Aurofac 2a appeared to have a depressing effect on the digestibility of protein and crude fiber. However, the effects of this supplement were not as great as those reported by Bell *et al.*, who fed crystalline aureomycin and a different type basal ration. Although the decrease in protein digestibility was statistically significant (P=.05), part of the decrease can be ascribed to the lower protein content of the aureomycin ration. Penicillin caused little change in the digestibility of the various nutrients. In Series A, Trial III, 100 mg. of the crystalline product produced a significant increase in the digestibility of crude protein and

TABLE 2. AVERAGE DAILY NITROGEN BALANCE

Trial No.	Treatment	Dry Matter Consumed	Nitrogen Consumed	Nitrogen Excretion			Nitrogen Balance [1]	
				Urine	Feces	Total		
		lb.	gm.	gm.	gm.	gm.	gm.	%
IV	Basal	14.03	127.5	43.4	42.3	85.7	41.8	32.8
V	Aureomycin, 32 and 100 mg.	14.58	103.6	49.1	40.5	89.6	14.0	13.5
VI	Penicillin, 32 and 100 mg.	13.98	103.6	54.4	36.4	90.8	12.4	12.0
VII	Penicillin, 400 mg.	13.98	104.7	54.9	36.0	90.8	13.8	13.2
VIII	Penicillin, 400 mg.	13.84	104.2	55.4	35.2	90.6	13.6	13.1

[1] Expressed in grams and as percent of intake.

a highly significant decrease in the digestibility of crude fiber; however, a repetition of this work in Series B, Trial VI, with another group of steers fed a different basal ration and antibiotic feed supplement containing penicillin revealed no significant differences between the supplement-feeding and basal periods.

The principal physiological effect observed which could be attributed to the feeding of an antibiotic was a change in the urine from a clear brownish color to a milky-looking suspension with a yellowish-green cast on the third and fourth days the steers were fed 400 mg. of penicillin. It was observed upon slaughtering steers fed 100 and 800 mg. of penicillin that the contents of the rumina were exceptionally dry and that the linings were somewhat redder than normal. No difference between the steers fed 100 and 800 mg. levels of the drug was noted.

As shown in table 2, there was a highly significant decrease in nitrogen retention during trials in which 32 and 100 mg. of aureomycin and 32, 100 and 400 mg. of penicillin were fed. A decrease in nitrogen intake may be responsible for part, but probably not all, of

this difference. There was apparently no difference in nitrogen retention between the various treatments.

All steers remained in a thrifty, normal condition throughout the series of trials, which may be partially verified by their average daily gains of 0.56 lb. in Series A and 0.90 lb. in Series B.

Results of the bacteriological tests in Series A as shown in table 3 indicated that as the amount of penicillin was increased the flora in

TABLE 3. AVERAGE GROUP DATA ON RUMEN FLORA AND ENVIRONMENT

Series	Trial	Antibiotic Feed	pH	Eh	Fiber Digestion in Artificial Rumen	Types of Rumen Organisms [1]	Evaluation of Flora
		mg.		(mv)		RO—	
A	III	200 mg. penicillin or less	...	...	...	HD, 6TBR	Good
A	...	400 to 800 mg. penicillin	...	...	...	Unidentified facultative anaerobes	Poor
		None	...	...	...	H, HD	Good
B	V	32 mg. aureomycin	7.2	−193	Fair	HD, H unidentified organisms	Good
B	V	100 mg. aureomycin	7.2	−197	Poor	Unidentified organisms, H, 6TBR	Fair
B	VI	32 mg. penicillin	7.1	−297	Fair	HD, H, unidentified organisms	Good
V	VI	100 mg. penicillin	7.1	−288	Fair	TRC, H, HD, PR, unidentified organisms	Good

[1] Rumen organisms isolated from top dilutions of rumen contents.

the rumen changed. The flora found in the steer fed 100 mg. of penicillin per day for 33 days and in the steer fed 100 mg. for 21 days and 200 mg. for 12 days were typical for adult ruminants and were similar to that found in the control animal. The steers fed 400 and 800 mg. the last 8 and 4 days of the trial, respectively, had a distinctly different flora from the other animals.

In Series B the penicillin-fed steers had a rumen environment and flora typical of that usually found in ruminants fed the type of basal ration employed in this experiment. Rumen conditions in the aureomy-

cin fed animals, especially those on the higher level, were less typical according to these criteria. The average pH in the groups compared was close to 7 and the Eh values were negative; however, the average negative Eh value of the penicillin-fed steers was larger than that of the aureomycin-fed animals.

The degree of fiber breakdown in the miniature artificial rumen was "fair" for all groups of steers in Series B except those on the higher level of aureomycin; in the latter group it was "poor." This finding correlated well with the types of rumen flora isolated. In steers fed the higher level of aureomycin, rumen flora was evaluated as only "fair" for rumen function as compared to "good" in the other steers. The data from the studies of the rumen flora and environment support the results of the digestion trials which indicated that the aureomycin supplement depressed protein and crude fiber digestibility more than the penicillin supplement.

Summary

Aureomycin and penicillin at different levels of intake were compared in digestion and nitrogen balance trials with steers. The results indicated (1) that aureomycin had a greater depressing effect than penicillin on the digestibility of protein and crude fiber, and (2) that the two supplements had about equal effect in decreasing nitrogen retention.

Penicillin fed at the rate of 100 mg. per day did not appear to upset the rumen flora and environment; whereas, 100 mg. of aureomycin resulted in a less desirable rumen flora for roughage digestion, the flora showing a decreased ability to digest fiber in the miniature artificial rumen.

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COMPENSATORY GROWTH OF BEEF CATTLE: THE EFFECT OF HAY MATURITY

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USUAL recommendations specify that wintering cattle should be fed so that continuous growth is maintained during this season. Morrison (1948) advises feeding calves so that they will gain ¾ to 1 lb. daily when summer grazing conditions are indicated to be good, and a minimum of ½ lb. daily with anticipated poor summer pasture. Guilbert *et al.*, (1944) have stated that continuous growth resulted in more efficient and economical gains than occurred if growth was retarded or restricted during the early development of the animal. Idaho workers have obtained similar results (Johnston *et al.*, 1952). Natural ration restriction occurs normally because of the seasonal variation in the quantity and quality of range forage. The amount, kind and nutritive value of wintering rations also contribute to this condition. Winchester (1953) and Winchester and Howe (1954) have pointed out that restricted growth may be a more economical method of raising beef cattle under some conditions. Their studies indicate that animals retarded in growth respond more rapidly when given adequate rations than do control animals and that only a small difference in body weight exists after a period on a normal ration.

Many western beef cattle are wintered on grass hay of variable quality, and subsequently grazed on the range the following summer. The purposes of the present experiment were (1) to determine the effect of hay harvested at two different stages of maturity upon the gains of beef cattle during the wintering period, and (2) to determine the extent that growing beef cattle will compensate for small winter gains the following summer.

Experimental Procedure

This experiment was conducted from 1945 to 1953 at the Knoll Creek Experimental Range Station located in northeast Elko County, Nevada. This area is above 5,000 feet in elevation with a consequent short growing season. Native mountain meadow hay was cut at two

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stages of maturity. The early-cut hay was harvested from June 25 to July 10, depending upon the season. This was before a maximum growth had been attained (Shipley and Headley, 1948). The late-cut hay was harvested from August 25 to September 15, from adjacent fields. Normally hay is harvested from July 1 to September 30 in this area, depending upon the season, lateness of spring grazing and competition of other work. The average chemical composition of the two hays is given in table 1. Weanling grade Hereford beef cattle were matched according to weight and allotted at random to two groups and fed either the early- or late-cut hay during the winter. Hay was fed

TABLE 1. AVERAGE CHEMICAL COMPOSITION OF EARLY- AND LATE-CUT HAY (1945–1953)

Item	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	Nitrogen Free Extract	Ash	Calcium	Phosphorus
	%	%	%	%	%	%	%	%
Early-cut hay	93.50	9.29	2.62	29.73	43.72	8.14	0.51	0.16
Late-cut hay	92.70	6.77	2.89	30.19	43.39	9.33	0.62	0.12

according to the appetites of the animals and water was continuously available. Salt was the only mineral supplied. Both groups of animals grazed the same summer range. During the first three years, the animals were grazed on open range and in later years on a fenced range allotment. This range was considered to be in excellent to good condition.

Three groups of weanling cattle were kept an additional winter and fed hay of the same stage of maturity used the previous winter, and two of these three groups an additional summer. The data were analyzed by the method of Snedecor (1946) for analysis of variance with multiple classification and disproportionate subclass numbers.

Results and Discussion

The response of weanling cattle to early- and late-cut hay during the winter and summer periods is summarized in table 2. It should be noted that the animals fed early-cut hay gained on the average three times more rapidly than those fed late-cut hay during the winter period. During the summer the cattle fed the late-cut hay tended to compensate for the previous winter treatment and gained more rapidly than the other groups. However, for the entire year the difference in

TABLE 2. THE EFFECT OF EARLY- AND LATE-CUT HAY UPON WINTER AND SUBSEQUENT SUMMER GAINS WHEN FED TO WINTERING WEANLING CATTLE (1945–1953)

Year	No. of Animals	Av. Initial Weight	Winter (I)			Summer (II)		Year (I & II)	
			Days	Av. Daily Gains	Hay Consumed Daily	Days	Av. Daily Gains	Days	Av. Daily Gains
1945–46									
Early-cut hay	14	535.5	100	1.50	15.7	197	0.83	297	1.05
Late-cut hay	10	533.5	100	—0.02	11.9	197	1.25	297	0.82
1946–47									
Early-cut hay	14	434.0	139	0.62	11.3	126	1.40	265	0.99
Late-cut hay	14	427.0	139	0.25	10.4	126	1.55	265	0.87
1948–49									
Early-cut hay	15	462.0	108	0.88	11.9	140	1.84	248	1.42
Late-cut hay	15	439.0	108	0.42	10.9	140	2.05	248	1.35
1950–51									
Early-cut hay	16	368.0	132	0.88	10.5	123	1.46	255	1.15
Late-cut hay	15	356.0	132	0.66	9.8	123	1.60	255	1.11
1952–53									
Early-cut hay	12	465.8	140	0.70	9.2	113	0.95	253	0.82
Late-cut hay	12	466.6	140	0.14	8.0	113	1.23	253	0.63
Average									
Early-cut hay	14.2	453.1	123.8	0.92**	11.7	140	1.29**	264	1.09**
Late-cut hay	13.2	444.4	123.8	0.29	10.2	140	1.54	264	0.96

** Difference is significant at the 1% level.

average daily gain, although smaller, was still in favor of the animals fed early-cut hay.

When cattle were fed either early- or late-cut hay for two consecutive winters, similar differences were obtained at the end of the second winter and summer periods. However, there was no difference between the gains of the animals for the two years regardless of the kind of forage that they had been fed for the preceding two winters (table 3).

These data show that hay cut at an early stage of maturity was markedly superior for promoting gains in wintering weanling and yearling cattle. Early-cut hay was adequate when fed alone to produce the gains suggested by Morrison (1948) as necessary for wintering beef calves (0.92 lb. daily). Although the animals fed the early-cut hay consumed approximately 1.5 lb. more hay daily, this was not sufficient to account for the wide difference in rate of gain between the two groups. The difference between the chemical composition of the two forages was more closely correlated to the response of the cattle (table 1). The late-cut hay did not contain adequate amounts of either protein or phosphorus to meet the nutritive requirements of the cattle (Guilbert *et al.*, 1950). Undoubtedly the digestibility and availability of the nutrients also decreased with forage maturity.

Consistently each summer, the animals that had been restricted during the winter gained more rapidly than the control animals. This phenomenon has also been observed by Winchester (1953), Winchester and Howe (1954), Dyer (1952), Guilbert *et al.*, (1944) and Nelson *et al.*, (1952), under various conditions. In the present study the ability of the animal to compensate for low winter gains appeared to be influenced by several factors: the age of the animal, the severity of winter growth retardation and the quantity of feed available during the summer. At the end of the summer grazing season, weanling cattle were not able to compensate fully for low winter gains while yearling cattle were able to catch up.

The smaller the difference in rate of gain after the winter feeding period, the better the animals were able to compensate for the period of retarded growth. The response of the cattle during the summer period varied significantly between years and probably reflects the amount of feed available which appeared to be influenced by the type of range grazed (fenced or open), the level of stocking, and the precipitation within the locality.

The years that the amount and quality of range forage were the best were the same years that the weanling animals fed late-cut hay

TABLE 3. THE EFFECT OF EARLY- AND LATE-CUT HAY UPON WINTER AND SUBSEQUENT SUMMER GAINS WHEN FED TO WINTERING WEANLING CATTLE RETAINED THROUGH A SECOND WINTER (1946–1952)

Year	No. of Cattle	Av. Initial Weight	Winter-Summer-Winter (I) Days	Av. Daily Gains	Hay Consumed Daily, Second Winter	Summer (II) Days	Summer (II) Av. Daily Gains	Both Years (I & II) Days	Both Years (I & II) Av. Daily Gains
1946–48									
Early-cut hay	14	434.0	473	0.83	17.0	147	1.61	620	1.02
Late-cut hay	14	427.0	473	0.69	16.0	147	1.90	620	0.98
1948–50									
Early-cut hay	15	462.0	501	0.90	19.2	127	1.84	628	1.04
Late-cut hay	15	439.0	501	0.69	18.0	127	2.39	628	1.03
1950–52									
Early-cut hay	16	368.0	489	0.85	17.5				
Late-cut hay	15	356.0	489	0.69	14.8				
Average									
Early-cut hay	15.0	421.0	466	0.86**	17.9	137	1.72**	624	1.03
Late-cut hay	14.7	411.0	466	0.69	16.5	137	2.14	624	1.00

** Difference is significant at the 1% level.

approached the gains of the animals fed early-cut hay after a summer on the range. Winchester (1954) has shown that retarded animals consume more feed daily than similar non-retarded animals when later fed an adequate ration. Although no quantitative data are available, the information presented here appears to verify this fact under range conditions.

These data have several practical implications. If cattle that are in poor condition in the spring consume more feed daily during the summer, these cattle would eat a disproportionate share of range forage in comparison to better-fed cattle. On open range with livestock stocking rates based entirely upon cattle numbers with no regard for condition of the animals, the amount of feed consumed by grazing animals would vary considerably. However, if adequate amounts of range forage are available and winter feeding costs are high, hay could be harvested at such time as to obtain maximum yield or with maximum convenience without incurring a serious penalty in regards to livestock weights the following fall when feeder cattle are sold. Better quality forage could be fed in more critical livestock enterprises. If feeders are sold as both weanling and yearling cattle, weanling animals should be fed the better roughage.

Under these range conditions, growing beef cattle were only temporarily retarded by feeding late-cut hay during the winter period even if this hay was deficient in protein, phosphorus and possibly other nutrients. At the end of the second summer the animals fed the late-cut hay were as heavy as those fed the better quality forage. No permanent stunting appeared even when no growth occurred during the entire winter feeding period.

Summary

Native mountain meadow hay harvested at two stages of maturity was fed to 137 wintering weanling and yearling beef cattle from 1945–1953. Significantly greater gains were obtained by the cattle fed early-cut hay during the winter feeding period. The restricted animals gained significantly more during the following summer, and at the end of the first year, the cattle fed the better quality forage still weighed significantly more than the animals fed late-cut hay, but the difference was small. Animals kept during a second year completely compensated for the two winters of restricted growth and were as heavy the second

fall as the animals fed early-cut hay. Animals restricted in growth were not permanently stunted and tended to compensate for this restricted period quite rapidly.

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INTERNAL PARASITISM OF BEEF YEARLINGS AS AFFECTED BY TYPE OF PASTURE, SUPPLEMENTAL CORN FEEDING, AND AGE OF CALF [1]

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THE development of better and more extensive winter grazing throughout the South has focussed attention on the problem of internal parasites, because forage is the intermediary conveyor of most worm infections of ruminants. The southern climatic fatcors that favor the establishment and growth of winter grazing also favor the propagation of parasites.

Beef calves which would ordinarily be sold in the fall as baby beef, or wintered in feed lots, are now often grazed on winter pastures for spring sale. Various kinds of winter pastures are now being studied in the South. On some of these pastures calves may be affected adversely by conditions favorable to internal parasitism. Taylor (1942, 1943, 1944a, 1944b) has shown that the type of herbage, conditions of forage growth, and the nutrition furnished to grazing animals, may influence the accessibility and parasitic phase of internal parasites. Roberts *et al.* (1952) stated that good nutrition is mainly concerned with the development and maintenance of a resistance to the effects of infection rather than to the infection itself. They observed that the effects of parasitism appear to persist in cattle to a greater extent than in other domestic animals. Laurence *et al.* (1951) clearly demonstrated the beneficial effects of higher corn intake on the response of sheep to verminosis, and Gordon (1948) showed that sheep grazing an oat crop threw off their nodular worm infections quicker than comparable sheep grazing "natural" pastures. That writer found, moreover, that the better nutritional status of the animals on oats evidently offset the effects of increased infections of *Haemonchus contortus* and *Trichostrongylus spp.* Lucker and Neumayer (1947) reported that lambs on a diet deficient in protein, iron, calcium and certain vitamins were more susceptible to infection with hookworm and less able to compensate for blood loss

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than comparable animals on a good ration of alfalfa and grain. Whitlock (1949) indicated that the overcrowding of lambs on pasture was of less significance than caloric intake in the prevention and control of trichostrongylidoses.

It has been observed by cattlemen that fall-dropped, or early calves quite often finish out better the second winter than spring-dropped or late calves, provided good pastures are available for the early calves. Roberts (1951) has suggested that early winter calves are more resistant than spring calves to parasitic infection during the following summer which is a rainy season in Queensland, Australia.

Studies to determine the parasitism of beef calves on winter pastures have not been conducted, heretofore, on an extensive basis in the South, a region known to be favorable to parasitism. This report gives the data of such a study made in Georgia, with reference to interrelationships between pasture type, supplemental feeding, ages of calves and internal parasitism.

Experimental

At the Georgia Experiment Station a project was conducted on the Piedmont Cooperative Land Use Area near Eatonton, Georgia, to determine the extent of internal parasitism of beef calves on three types of winter pasture.[4] During the winters and springs of 1950 through 1953, inclusive, grade Hereford calves were placed on two paddocks of each, of three types of winter pasture, namely, (1) temporary (rye grass, oats, and crimson clover), (2) fescue-white clover, and (3) crimson clover. The calves were divided into the groups for each of the pastures on the basis of age, parasite load as indicated by worm egg counts, weight, and feeder grade. This was done at the time of the first grazing available each year, usually fescue or fescue and temporary. The crimson clover was always from one to three months later in providing adequate forage. Even though there was a difference in time of start of grazing, the pastures were grazed when ready as is the case under actual farm conditions.

It was assumed that all lots were free of contamination with infective stages of cattle nematodes at the beginning of the tests in 1950, as the pastures had been prepared within the previous year and had not been grazed within the previous two years. Grass samples were not taken before the tests in 1951 and 1952 to determine the carry-over of infec-

[4] Appreciation is expressed for the generous cooperation of Mr. W. T. Fullilove and Mr. E. C. Cross in providing the facilities that made these experiments possible.

tive larvae, but at the start of the test in 1953 forage samples from all of the pastures were examined. Though no larvae were found in fescue and temporary forage clipped at a height of one inch at the start of the tests in December, the forage from one of the crimson clover pastures showed seven larvae per lb. of forage at the beginning of grazing in February. Since the average temperature for the month of December was 45° F. and a gradual increase occurred to an average of 53° F. in February, the non-recovery of larvae on fescue in December may have been due to lack of migration onto the grass, or perhaps to poor survival during the lower temperatures of December. The examinations indicated that there was a negligible summer carry-over on most plots. If any forage was cleaner from a parasite standpoint than another, it probably was the temporary pastures which were disked and seeded annually.

Each year, during the period of the test, fecal egg counts were made every 28 days, large numbers of eggs being counted by the dilution technic and small numbers by the flotation technic of Stoll (1930). The egg counts are shown in the tables as the average egg count for all of the animals in each group for the entire period of the test for each pasture. Postmortem studies were made at the end of the grazing season, the numbers of the different species of worm parasites being estimated by the postmortem technic described by Porter (1942). The worm loads of two or three typical calves in each group were determined, the basis of selection of these calves being their age, weight, and parasite egg count. Any gross pathology of the intestinal tract was also observed in the same animals whose worm loads were counted. Although worm loads at autopsy were determined for only about one-third of the calves, the sampling was considered to be sufficiently adequate to give averages on which significant conclusions could be based. To simplify the presentation of results and the tabular material, the worm and larval counts have been converted to the closest 1,000.

Experiments I and II, 1950 and 1951. Supplemental Corn Feeding Versus No Corn Feeding on Pasture

In 1950 and 1951 one group of calves on each type of pasture was given a corn supplement, while another comparable group of calves had access to forage alone. In 1950 the average daily amount of shelled corn consumed was 4.3 lb. per animal, while in 1951 ground snap corn

was consumed at the rate of 5.1 lb. The calves on crimson clover consumed about 1½ lb. less corn per day than those in the other two lots, due to a shorter test period. The amount of corn offered was approximately equalized for all groups. In 1950, six animals per lot were used, but in 1951 the number of animals in the no-corn lots was reduced to five to compensate for the anticipated increased carrying capacity where corn was fed. At the start of the tests the first year the average age of the calves was 11 months, while in the second year it was 10½ months. When the experiment was repeated in 1951, the supplemented and unsupplemented lots were reversed to offset any possible differences in larval contamination and survival.

In 1950 and 1951 the forage growth was retarded, in 1950 by a dry fall and winter, and in 1951 by extremely cold weather in November and again in January. In 1950 the forage in all pastures was generally inadequate at the beginning of the tests, and remained generally insufficient on the fescue pastures. However, the temporary pastures provided abundant grazing late in the season. In 1951 the fescue forage was abundant, but grazing was insufficient during the early part of the season on temporary forage and on the crimson clover lot in which the calves received corn.

Experiments III and IV, 1952 and 1953. Fall Versus Spring-Dropped Calves on Pasture

During 1952 and 1953 the same pastures were used, but a new experiment was conducted to compare the parasitism of fall or early calves, 10½ to 11½ months old at the start of the test, with that of spring or late calves, 8½ months old, on each type of pasture. The number of animals per lot was adjusted to the carrying capacity of the pasture, considering the average weight of the animals in each group. The average age of the fall calves in 1952 was 11½ months and that in 1953 was 10½ months. As in the previous experiments, the lots were reversed between 1952 and 1953.

In 1952 the amount of forage was abundant for the entire grazing period, except for the first 3 weeks on crimson clover and temporary pastures. In 1953 the fescue grass was short, but the temporary pastures were in good condition at the start of the tests. The quality of the crimson clover pastures was lowered by a considerable amount of cheat grass, which was present later in the season.

Results

Experiments I and II, 1950 and 1951. Supplemental Corn Feeding Versus No Corn Feeding on Pasture

The effect of the addition of corn to the ration was a statistically significant (5 percent level of probability) reduction in the worm load, except in calves on crimson clover in 1950. This indicated difference in worm load was especially noticeable between the two groups on fescue in both years, and was generally of more significance between the groups on all pastures in 1951 (tables 1 and 2). The average worm load in 1950 of the groups receiving corn supplement was 5,000 compared with 18,000 for the groups receiving no corn. In 1951 the average worm load at postmortem of the supplemented groups was 17,000, whereas the no-corn groups had an average of 57,000. Also noted in both years was the presence of greater numbers of immature or larval worms in cattle not getting a supplement of corn than in those getting this supplement. This appears to indicate that the cattle showing immature worms were still acquiring and retaining heavy loads of young parasites.

Cattle on the fescue pasture not receiving corn were the most heavily parasitized of all of the animals (tables 1 and 2). In 1951 they were in poor finishing condition at the end of the test and brought a lower selling price than comparable calves from the other pastures. However, the calves on fescue with supplemental corn had only one-third as many worms as the calves without supplement and made a much larger average daily gain (table 2).

It was found also that the amount of estimated forage consumed, as determined by cage and mower strip method, during April and May, 1950, was actually slightly higher among the animals on fescue receiving a small amount of corn supplement. The two groups of calves on temporary forage and crimson clover consumed almost equal amounts of forage, regardless of whether they were or were not supplemented with corn. Therefore, the lower worm loads of the supplemented calves in that year were apparently not due to decreased forage consumption but to a better nutrition.

The principal parasites involved and the percent of the total adult worm load in 1950 and 1951, were the stomach worms, *Ostertagia ostertagi* (46 percent), *Trichostrongylus axei* (25 percent), and intestinal roundworms, *Cooperia punctata* (13 percent) and *C. oncophora* (15 percent). Almost a third of the total worm loads consisted of

larval worms, of which 91 percent were recovered from the fourth stomach.

The corn supplement furnished to the calves grazing temporary

TABLE 1. EFFECTS OF SUPPLEMENTAL FEEDING AND THREE TYPES OF WINTER PASTURE ON PARASITISM AND GAINS OF YEARLING BEEVES. 1950 [1]

Item	Fescue		Temporary		Crimson Clover	
	Corn	No Corn	Corn	No Corn	Corn	No Corn
Test began	Feb. 1	Feb. 1	Feb. 1	Feb. 1	Mar. 29	Mar. 29
No. days on test	112	112	112	112	56	56
No. cattle on test	6	6	6	6	6	6
Average daily gain (lb.)	2.50	1.65	2.32	2.39	2.52	2.34
Average of egg counts [2]	124	125	67	39	18	11
No. cattle exam. postmortem	2	2	2	2	2	2
Worm load, (mean)	6	43	5	10	3	1.5
including larvae (range) (thousands)	.3–12	30–56	4–6	.8–19	.7–6	1–2
Av. no. larvae (thousands)	0	20	.2	0	0	0

[1] See text (Results) for statistical interpretation.
[2] Number of roundworm eggs per gram of feces, expressed in the average for entire period of test.

TABLE 2. EFFECTS OF SUPPLEMENTAL FEEDING AND THREE TYPES OF WINTER PASTURE ON PARASITISM AND GAINS OF YEARLING BEEVES. 1951 [1]

Item	Fescue		Temporary		Crimson Clover	
	Corn	No Corn	Corn	No Corn	Corn	No Corn
Test began	Jan. 19	Jan. 19	Mar. 21	Mar. 21	Feb. 21	Feb. 21
No. days on test	145	145	84	84	84	84
No. cattle on test	6	5	6	5	6	5
Average daily gain (lb.)	2.08	1.13	2.99	2.89	2.18	2.45
Average of egg counts [2]	94	197	147	108	225	156
No. cattle exam. postmortem	2	2	2	2	2	2
Worm load, (mean)	36	107.5	2	17	12	47
including larvae (range) (thousands)	13–60	107–108	1–3	5–30	.5–24	26–69
Av. no larvae (thousands)	10	58	.1	11	0	2

[1] See text (Results) for statistical interpretation.
[2] Number of roundworm eggs per gram of feces, expressed in the average for entire period of test.

forage or crimson clover did not give increased gains as it did for the calves grazing on fescue, despite the fact that the former calves receiving supplemental corn had, as a rule, fewer worms than their mates eating only forage. This lack of response to corn supplement indicated that the temporary and crimson clover forages were ample and of good quality, whereas the additional nutrients furnished by the corn provided a higher plane of nutrition only for the animals on fescue forage, which by itself is apparently inadequate. It also indicated that the calves on crimson clover and temporary forages were not affected adversely by their worm loads, presumably because of the higher plane of nutrition which these forages furnished. Considerable evidence has recently accumulated, McCullough (1953) and McCullough *et al.* (1953), that fescue grass has a lower nutritive value than temporary forage, from the standpoint of dry matter intake, low digestibility and low T.D.N. value. The low dry matter intake is apparently due to the lower digestibility and the greater bulkiness of fescue grass.

Experiments III and IV, 1952 and 1953. Fall Versus Spring-Dropped Calves on Pasture

The difference between the worm loads of fall and spring calves was statistically significant at the 1 percent level. In 1952, with 3 months difference in the average age of each group, the disparity between the high worm loads of the younger calves and the low worm loads of the older calves was very great for those on crimson clover and temporary grazing, while it was slight between the two groups on fescue (table 3). This would indicate that the acquired immunity including that due to the age of the older calves on fescue was nullified by the poor nutritional quality of fescue grass plus the continuous larger intake of infective larvae. The results of examinations to be mentioned later showed fescue to be the most heavily contaminated of the three forages. Not only were the spring calves more susceptible to infection, but they were probably exposed to more infective larvae because they had, as a rule, higher average egg counts when placed on the pastures and maintained higher counts during the entire period of the tests (tables 3 and 4).

The principal parasites recovered at necropsy and the percent of the total adult worm load in 1952 and 1953 were the stomach worms, *O. ostertagi* (35 percent), and *T. axei* (52 percent), and the intestinal roundworms, *C. punctata* (5 percent), *C. oncophora* (3 percent) and *T. colubriformis* (5 percent). About 60 percent of the total worm loads

consisted of larval forms, of which 97 percent were recovered from the fourth stomach.

The average worm load in 1952 of the fall-dropped or early calves

TABLE 3. EFFECTS OF THREE TYPES OF WINTER PASTURE ON PARASITISM AND GAINS OF FALL AND SPRING-DROPPED BEEF CALVES. 1952 [1]

Item	Fescue		Temporary		Crimson Clover	
	Fall	Spring	Fall	Spring	Fall	Spring
Test began	12/12/51	12/12/51	2/6/52	2/6/52	2/6/52	2/6/52
No. days on test	168	168	112	112	112	112
No. cattle on test	7	8	8	10	6	7
Average daily gain (lb.)	.86	.33	2.13	1.92	1.43	1.68
Average of egg counts [2]	239	476	120	252	174	290
No. cattle exam. postmortem	2	3	2	3	2	3
Worm load, (mean)	152	167	7	142	4	251
including larvae (range) (thousands)	151–153	115–237	6–9	44–255	.3–8	204–297
Av. no. larvae (thousands)	107	92	5	73	.3	149

[1] See text (Results) for statistical interpretation.
[2] Number of roundworm eggs per gram of feces, expressed in the average for entire period of test.

TABLE 4. EFFECTS OF THREE TYPES OF WINTER PASTURES ON PARASITISM AND GAINS OF FALL AND SPRING-DROPPED BEEF CALVES. 1953 [1]

Item	Fescue		Temporary		Crimson Clover	
	Fall	Spring	Fall	Spring	Fall	Spring
Test began	12/8/52	12/8/52	12/8/52	12/8/52	2/25/53	2/25/53
No. days on test	163	163	163	163	84	84
No. cattle on test	7	9	8	10	6	7
Average daily gain (lb.)	.67	.67	1.84	1.70	1.84	1.45
Average of egg counts [2]	147	201	166	222	71	83
No. cattle exam. postmortem	2	3	2	3	2	2
Worm load, (mean)	47	99	7	13	7	17
including larvae (range) (thousands)	10–84	80–124	4–9	6–19	2–11	1–32
Av. no. larvae (thousands)	30	63	3	4	5	6

[1] See text (Results) for statistical interpretation.
[2] Number of roundworm eggs per gram of feces, expressed in the average for entire period of test.

as a group was 54,000 as compared with 179,000 for the spring-dropped or late calves. Their average daily gains were 1.47 lb. and 1.31 lb., respectively. In 1953 the early calves had an average of 20,000 worms while the late calves showed an average of 46,000. Their average daily gains were 1.45 lb. and 1.27 lb., respectively.

In 1953 there was a difference of only two months in the average ages of the early and late groups of calves. Yet the average worm load of the younger calves was more than twice that of the older calves. If cattlemen have good winter pastures available or an acceptable feeding program for their cows during the late fall and early winter, the early dropping of calves would seem to aid in the control of parasitism in their calves during the next year's period of growth and finishing for market.

Yearly Variation and Pasture Effect on Parasitism (*4 years*)

The difference in average worm loads in different years, comparing only the unsupplemented groups of 1950 and 1951 with the spring calves of 1952 and 1953, was highly significant ($<.01$). The average worm loads in the above years were 18,000, 57,000, 179,000 and 46,000, respectively. Also, the average egg counts per gm. of feces for the calves for the corresponding 4 years were 64, 152, 259 and 148, respectively. In 1952, the year in which parasitism was heaviest (table 3), an abnormally warm winter was followed by excessively wet weather in March, with over 12 inches of rainfall. This, combined with the generally high parasitism of the animals at the beginning and during the test, created conditions favorable to the development of heavy parasitic infections in the spring calves and the occurrence of clinical helminthiasis among the calves on fescue pastures. Preliminary studies of the numbers of infective larvae per lb. of green forage on the three types of pasture involved in this investigation showed average larval populations of 415, 48 and 28 larvae per lb. of forage in 1952 on fescue, crimson clover and temporary pastures, respectively, the highest recovery being 1,476 per lb. of fescue on April 19. The periods of high larval recovery from forage in 1952 and 1953 occurred during March, April and early May, when the average daily temperatures were between 55° and 67° F.

The summer of 1952 was the warmest on record, with severe drought in June and July, followed by a very cool and dry fall. These conditions probably were responsible for the previously mentioned low carry-over of larvae to the 1953 winter grazing season. The low worm loads in 1953 (table 4) were evidently due to this low carry-over,

the subsequent lower contamination from more lightly infected animals, plus relatively lesser development of larvae during the 1953 grazing season. This was evidenced by lower average larval recoveries from the forages than in the 1952 season. The number of infective larvae recovered in 1953 from fescue, crimson clover and temporary forages were 38, 17, and 1, respectively.

The differences in worm loads between the calves on the different types of pastures were statistically significant at the 5 percent level in all four years. In three of the years (tables 1, 2 and 4) the average worm loads of the calves on fescue were higher than those of comparable animals on crimson clover or temporary grazing. In 1950 (table 1) the close grazing and insufficient forage for the unsupplemented calves on fescue favored the maintenance of heavier loads of internal parasites and a lower rate of gain than for comparable calves on temporary or crimson clover forage. In 1951 (table 2) the lower gain and higher worm load for the calves on fescue not receiving corn was more accentuated, and again in 1953 (table 4) the differences between the spring group on fescue and similar calves on the other types of pasture were great in relation to worm loads and average daily gains.

In 1952 (table 3) the spring calves on crimson clover had a much higher worm load than comparable calves on fescue pastures; also, the latter animals despite their lower worm load, made very poor gains as compared to those on crimson clover, and showed lesions indicative of severe infection with stomach worms. Severe edema and erythema of the abomasum were observed at postmortem in two of the three animals killed from the fescue lot in 1952, while only one of the two animals killed from the crimson clover pasture showed a moderate erythema of the fourth stomach. No pathology was observed in any of the animals on temporary pasture. The fall calves on fescue in 1952 had a much higher worm load than comparable calves on the other types of grazing, and one of the two animals killed from that lot showed pethechial hemorrhages in the pyloric portion of the abomasum, whereas comparable calves on crimson clover and temporary pastures showed no pathology postmortem.

Lesions which were indicative of clinical parasitism were observed also in 1953 (table 4) in the spring calves on fescue. The pathology of the fourth stomachs was similar to that seen in 1952 but was not as pronounced or extensive. All other calves, including fall and spring groups, showed no pathology at necropsy.

In all years, except 1950, the calves grazing on fescue showed

clinical symptoms of parasitism, such as rough and dull hair coats, diarrhea, and emaciation. These symptoms were especially evident among the unsupplemented calves on fescue in 1951 and among the spring calves on fescue in 1952 and 1953. None of the calves on crimson clover or temporary pastures ever showed symptoms of clinical parasitism, regardless of their worm load.

In 1950 and 1953 the start of grazing on temporary and fescue pastures occurred at the same time, but in 1951 and 1952 the grazing on temporary pasture was delayed as was also that on crimson clover. Notwithstanding the annual preparation of temporary pastures and the shorter grazing periods for crimson clover, there are years, for example, 1952, when conditions favorable to parasitism lead to heavy worm acquisition, regardless of the type of pasture. In such years especially, the nutritive value of a pasture may determine whether the calves will be helped or hindered in their struggle to maintain resistance to the harmful effects of parasitism. Taylor (1944b) has aptly stated that parasitic disease "is a matter of extent of infestation per unit of nutrition" or "of numbers of larvae per calorie." The results in this work have validated this relationship.

Summary

The following general conclusions may be drawn from the data herein reported:

Calves on fescue pastures had heavier worm loads at autopsy, or showed more harmful effects of parasitism, than similar calves on temporary winter or crimson clover pastures. This was due, at least partly, to a lower nutritive value of the fescue grass. Conversely, the high nutritional quality of temporary and crimson clover forages appeared be a factor in checking the harmful effect of large numbers of parasites which were sometimes acquired on these pastures.

Calves on each type of pasture that received corn supplement generally had fewer worms than those on the same types of pasture without corn supplement.

Spring-dropped, and, therefore younger calves, as a group, had from two to three times as many worms as the fall-dropped or so-called early calves. A difference of only two months in time of dropping of calves resulted apparently in a considerable difference in the degree of parasitism.

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THE EXCRETION OF VITAMIN B_{12} BY DAIRY CATTLE

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THERE is abundant evidence that vitamin B_{12} occurs in considerable quantity in the feces of ruminants. That most of it is synthesized by microorganisms in the digestive tract is highly probable. It has been demonstrated, for example, (Pearson *et al.*, 1953) that relatively large amounts of this vitamin are synthesized in the gastrointestinal tract of sheep. For cows, however, while similar data have been presented for some of the B vitamins (Teeri *et al.*, 1950, 1951), no quantitative measurements of the synthesis of B_{12} have been reported previously. Such data are presented in this report.

Experimental

Two groups of dairy cattle were used in this study. The first consisted of four adult Guernseys (ages 5, 7, 3 and 5 years) and was used during 1952–53 to establish quantitatively the excretion of vitamin B_{12}. The second group, consisting of two Ayrshires and two Guernseys (ages 1–2 years), was used during 1953–54 to study the excretion of this vitamin when the ration consisted of hay with oats or hay with corn.

By maintaining the animals in metabolism stalls, it was possible to make regular collections of 24-hour urine and feces samples. Collections and preservation of these samples were as previously reported (Teeri *et al.*, 1950). The lengths of the collection periods were from 14 to 17 days.

Analyses for vitamin B_{12} were carried out microbiologically with Lactobacillus leichmannii (A.T.C.C. number 7830) as the test organism.

Results and Discussion

Experiment I

In this experiment all animals were fed the same ration consisting of oats and hay. As the daily consumption was approximately the same for each animal, an average value could be taken to represent the daily intake, and by analysis this was found to contribute 47.6 micrograms of vitamin B_{12} per day.

[1] Published with the approval of the Director of the New Hampshire Agricultural Experiment Station as Scientific Contribution No. 173.

The average daily excretions of vitamin B_{12} by each cow are presented in table 1. The fact that approximately 99 percent of the excreted vitamin B_{12} was in the feces is in very close agreement with the findings of Pearson *et al.* (1953) with sheep, and supports their suggestion that this vitamin is either poorly absorbed or that it is metabolized to some other compounds.

The amount of vitamin B_{12} synthesized in the gastrointestinal tract is relatively very great. Under the conditions of this experiment the excretion exceeded the intake 40 to 55 times. It is likely, furthermore, that the extent of synthesis of this vitamin in the intestinal tract of

TABLE 1. AVERAGE DAILY EXCRETIONS OF VITAMIN B_{12} BY COWS (HAY AND OATS RATION)

Cow Number	Feces	Urine	Total
	mcg. Vitamin B_{12} per day		
1	1980.2	7.5	1987.7
2	2049.8	13.7	2063.5
3	1967.4	15.3	1982.7
4	2663.9	11.4	2675.3

Average daily intake, 47.6 mcg. B_{12}.

cows might well be affected by alterations in the ration, as has been demonstrated for other vitamins (Teeri *et al.*, 1950, 1951) and for B_{12} in sheep (Pearson *et al.*, 1953). Comparison of these data with those of the following experiment, involving considerably younger animals, indicates that age also may have an influence on the extent of B_{12} synthesis. This could be related to the establishment in the rumen or intestinal flora of those microorganisms which synthesize this vitamin, or simply to the greater bulk of the rumen content in the older, and larger, animals.

Experiment II

The age of the animals used in this experiment (approximately 1½ years) was considerably less than in Experiment I, and this fact is reflected perhaps in the less extensive synthesis of vitamin B_{12}. In all cases, however, the excretions were significantly greater than the intakes, showing that a considerable amount of this vitamin was being formed.

The rations studied consisted of hay with oats and hay with corn. The degree of fineness of the oats (crimped or ground) and corn (flaked or ground) also was studied, but as it had no significant effect on B_{12} synthesis, the data in each case were averaged. The results, presented in table 2, indicate a considerable amount of B_{12} synthesis by the rumen microorganisms on both rations. While there were appreciable variations in total excretions among the individual animals, no significant differences were attributable to the different rations.

Since most of the excreted vitamin is found in the feces, it represents, in great part, a waste product as far as the ruminant itself is

TABLE 2. AVERAGE DAILY EXCRETIONS OF VITAMIN B_{12} BY YEARLING HEIFERS ON THE TWO RATIONS [1]

Cow Number	Hay and Oats	Hay and Corn
	mcg. B_{12} excreted per day (feces and urine)	
5	357.2	983.0
6	441.2	636.0
7	708.9	437.6
8 [2]		604.5
Av.	502.4	665.2

[1] Average daily intakes of vitamin B_{12} on the two rations were: hay and oats, 36.2 mcg.; hay and corn, 28 mcg.
[2] Cow number 8 did not receive the oat ration.

concerned. Therefore, although the amount of vitamin B_{12} synthesized in the rumen is unquestionably very great, it is doubtful that the full extent of this action is often of importance to the ruminant on most rations, unless the amount metabolized and not recovered is also very great. On a ration devoid of vitamin B_{12}, however, the rumen synthesis of this vitamin is unquestionably of great importance.

Summary

The extent of vitamin B_{12} synthesis in the gastrointestinal tract of dairy cattle has been indicated by quantitative intake and excretion data. The amount of such synthesis is relatively very great, the excretion exceeding the intake, in the case of the older animals, 40 to 55 times, on a ration of mow-cured hay and oats. Rations containing either oats or corn do not differ significantly in their favorable effect on the rumen synthesis of vitamin B_{12}. Very little B_{12} was found in the urine, nearly all of that excreted being in the feces.

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A STUDY OF THE UTILIZATION OF PSEUDO VITAMIN B_{12} BY THE DAIRY CALF

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DRAPER *et al.* (1952) reported a vitamin B_{12} deficiency in calves manifested by a cessation of growth, poor appetite, and in some cases incoordination. They also found that growth was resumed following liver extract or crystalline B_{12} therapy. Ford *et al.* (1953) report that only a small proportion of the vitamin B_{12} activity of rumen contents is due to vitamin B_{12} itself, whereas the liver of cattle contains B_{12} and little or no cyano-ω-cobalamin or fractions B or C. They suggest that cobalt is necessary not only to form B_{12} for the animal, but also to form cyano-m-cobalamin and the other factors B, C, etc., which may be important in the rumen for normal microbial function, but not necessary for the animal. The purpose of these experiments was to study the utilization of one of these microbial forms, *i.e.*, pseudo vitamin B_{12} (the form of vitamin B_{12} containing adenine rather than dimethylbenzimidazole) by the young dairy calf. The study of the activity of pseudo vitamin B_{12} for the calf would be interesting, since the compound is made in the rumen, ruminants might be able to utilize it.

Experimental

Experiment I

Calves were maintained on a synthetic diet (Hopper *et al.*, 1954) in which the protein source was Drackett soybean "protein 220" [2] for a period of 17 weeks. The calves were housed and fed in a manner similar to that reported by Draper *et al.* (1952). Calf No. 2, a Jersey male, remained with its dam 3 days after birth and then was placed on the synthetic diet. This calf received 1 γ of crystalline vitamin B_{12} per kg. body weight per day injected intramuscularly once a week. Calf No. 3, a Guernsey male, also remained with its dam for a 3 day period following birth, and was fed the synthetic milk diet until a B_{12} deficiency had apparently developed; it then was given 1 mg. of pseudo B_{12} per week by injection to try to correct the deficiency.

[1] Department of Animal Nutrition, Urbana.
[2] Manufactured by the Drackett Co., Cincinnati, Ohio.

Experiment II

Two Guernsey calves, Nos. 4 and 5, were housed and fed as in the preceding experiment. Both calves received pseudo vitamin B_{12} at the level of 1 γ per kg. body weight per day injected intramuscularly once a week. Calf No. 6, a Brown Swiss, received crystalline vitamin B_{12} at the same level. These calves were removed from the experiment after

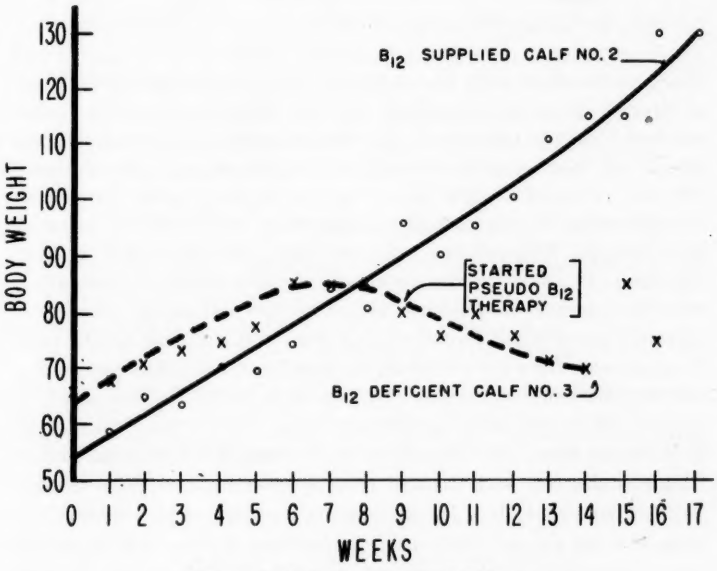

Figure 1. Growth Curves of Calves.

40 to 56 days and liver samples were obtained for vitamin B_{12} assay by the E. Coli mutant (Burkholder, 1951) and Ochromonas malhalmensis (Hunter *et al.*, 1953).

Results and Discussion

As seen in figure 1, the growth curve of calf No. 3 did not improve after administration of pseudo vitamin B_{12}, while calf No. 2, receiving crystalline B_{12}, continued to grow well during this period. This would seem to suggest that pseudo B_{12} was not active for supporting weight gains.

Experiment II was planned to study the possible absorption and liver

TABLE 1. WEIGHT GAINS OF CALVES RECEIVING PSEUDO B_{12} AS COMPARED TO VITAMIN B_{12}

Calf No.	Treatment	Days on Trial	Beginning Wt. (lb.)	Final Wt. (lb.)	Ave. Daily Gain (lb.)
4	Pseudo B_{12}	56	70.5	117.5	0.84
5	Pseudo B_{12}	40	81.0	86.0	0.12
6	Vitamin B_{12}	47	113.0	158.0	0.96

storage of pseudo vitamin B_{12} by the calf rather than complete depletion of vitamin stores and subsequent therapy. Therefore the calves were removed from the trial before the vitamin stores were completely depleted and liver samples obtained for vitamin assay. Upon autopsy, calf No. 5 showed a slight hemorrhage in the heart tissue. There was no explanation for this pathological condition, which was not found in any other calf. This calf also exhibited slow growth as seen in table 1, and due to this slow growth, apparently the liver stores of vitamin B_{12} were not depleted to the same extent as in the case of calf No. 4. Although calves 4 and 5 received only pseudo B_{12} throughout the trial, it can be seen from the results of the assay in table 2 that pseudo B_{12} and/or other forms were apparently present in the liver of the calves, as the E. Coli mutant assay gave higher values in all cases than did the Ochromonas assay, the latter being said to respond only to vitamin B_{12}. This was also true with the calf (No. 6) receiving crystalline vitamin B_{12}, but no pseudo B_{12}. It thus appears that the pseudo vitamin B_{12} being injected was not being stored in the livers of calves due to the low values obtained from the liver assay using the E. Coli mutant. If there was storage, it would seem that these values would be higher when pseudo vitamin B_{12} is injected at the levels used in this trial.

TABLE 2. B_{12} ASSAY OF LIVERS OF CALVES

		Assay Organism	
Calf No.	Treatment	E. Coli Mutant γ/gm. Fresh Liver	Ochromonas γ/gm. Fresh Liver
4	Pseudo B_{12}	0.11	0.072
5	Pseudo B_{12}	0.50	0.34
6	Vitamin B_{12}	0.75	0.58

Summary

From these results pseudo vitamin B_{12} appears to be inactive in replacing vitamin B_{12} for growth of the dairy calf.

Other forms of vitamin B_{12} seem to be present in the liver of all calves receiving the synthetic diet.

Acknowledgments

The pseudo vitamin B_{12} used in this trial was supplied through the courtesy of Dr. J. J. Pfiffner, Research Laboratory, Parke, Davis and Co., Detroit, Michigan.

The authors also wish to express their appreciation to Dr. D. A. Willigan, College of Veterinary Medicine, University of Illinois for the autopsy of the calves used in these trials.

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THE EFFECTIVE BUOYANCY OF THE RUMEN JUICE OF CATTLE FED HAY, GRASS AND FRESH LEGUMES [1, 2, 3]

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RUMEN digestion of any feed entails the production of gas. Bubbles of gas formed in the lower regions of the paunch have greater distances to travel before they can burst and release their gas into the dome of the organ than those formed in the upper regions. If enough small bubbles are produced in the lower regions of the rumen, they may be retained in the paunch fluid and a frothy mass develop. It is reasoned that the relative position of a feed in the paunch is a function of the density of the feed and the density of the paunch juice. The effective buoyancy of rumen juice can be expressed as its specific gravity. The density of living plants, however, has not been measured successfully.

Because of the gas bubbles in foamy liquid, its density can be expected to be less than that of liquid without the bubbles. Frothy liquid is, then, less buoyant than non-frothy liquid. When the animal is fed feeds which have a tendency to sink before undergoing most of their gaseous digestion, the contents of the lower part of the paunch can be expected to contain more bubbles of gas, be less dense and thus less buoyant to new feed entering the organ. It is suspected that fresh legumes are more likely to sink to the bottom of the paunch than hay or grass. If this is true, the contents of the ventral sac should be lower in specific gravity following the intake of fresh legumes than following the intake of hay or fresh grass. The present report covers a comparison of the specific gravities of rumen liquors following the feeding of hay, grass and green legumes.

[1] With the technical assistance of Miss Kathrine Penn, Mrs. Maxine Manthei and Mrs. R. A. Postweiler.

[2] Published with the approval of the Director of the Agricultural Experiment Station, Madison, Wisconsin. Results of co-operative work between the Wisconsin Agricultural Experiment Station and the Bureau of Plant Industry, Soils and Agricultural Engineering, (Division of Forage Crops and Diseases), United States Department of Agriculture. Supported in part by the Research Committee of the Graduate School with funds from the Wisconsin Alumni Research Foundation.

[3] Department of Veterinary Science Paper No. NS 162.

Methods

Two mature rumen-fistula cows were manger-fed morning and afternoon and offered water before each feeding. Each feed was fed alone. The hay was a poor quality mixed hay with less than 5 percent legumes. The grass was a fence-row mixture containing bluegrass, orchard grass and many other varieties. The alfalfa was nearly pure and prebloom. The clover was 80 percent red, 10 percent ladino and 10 percent alfalfa. The red clover was 10 percent in bloom at the start of the feeding period and 80 percent in bloom at the end of the feeding period. Both the ladino and alfalfa in the clover mixture were prebloom when fed. All green feed was cut fresh the day fed. From 3 to 7 trials were conducted with each animal on each feed.

Specific gravities of samples of strained and of centrifuged juice from the ventral sac of the rumen were determined using twenty-five ml. specific gravity bottles, immediately before, approximately ½ hour after and approximately 2 hours after the intake of the morning feed and water. The average water consumption between the sampling times, the average daily water intake, the average amount of feed fed between the sampling times and the average daily feed intake were determined.

Results

Means for the strained and centrifuged portions of all samples taken at each of the three sampling times for each cow and each feed were calculated and are listed in table 1. Differences between the mean specific gravities of the sampling times before and ½ hour after feeding, and before and 2 hours after feeding, for strained and for centrifuged samples for each cow and each feed were tested statistically. Differences between the mean specific gravities of the ½ hour samples of different feeds were also tested.

Approximately one-half hour after the intake of feed and water the specific gravities of ventral sac liquor were significantly lower than those of the corresponding samples before feed and water. Water intake was greatest with hay feeding and least with legume feeding. Specific gravities of centrifuged samples one-half hour after feeding were altered the least when legumes were fed and water intake was lowest and were significantly reduced when hay and grass were fed and water intake was greatest. Specific gravities of strained liquor one-half hour after intake of legumes were significantly lower than after the intake

TABLE 1. CHANGES IN THE SPECIFIC GRAVITY OF RUMEN JUICE FOLLOWING INTAKE OF WATER, HAY, FRESH GRASS AND FRESH LEGUMES

Feed	Hay		Grass		Alfalfa		Clover	
Cow No.:	1	2	1	2	1	2	1	2
Water (lb.) †	48/93	22/53	21/49	13/44	3/35	4/32	0/11	8/27
Feed (lb.) ‡	13/23	8/14	26/44	22/31	28/49	20/39	16/60	15/50
Strained								
Before	1.0110	1.0113	1.0108	1.0103	1.0078	1.0044	1.0094	1.0075
½ hour	1.0065**	1.0079**	1.0042**	1.0028**	1.0005**	0.9871**	0.9815**	0.9828**
2 hour	1.0094*	1.0095	1.0094*	1.0106	1.0072	0.9967**	1.0034**	0.9927**
Centrifuged								
Before	1.0104	1.0091	1.0101	1.0094	1.0087	1.0085	1.0091	1.0097
½ hour	1.0084**	1.0070**	1.0089*	1.0088	1.0090	1.0087	1.0096	1.0085
2 hour	1.0082**	1.0076*	1.0096**	1.0089**	1.0093	1.0091	1.0087	1.0096

† 1st figure is water consumed between the before and ½ hour samplings. 2nd figure is total daily intake.

‡ 1st figure is feed fed between the before and ½ hour samplings. 2nd figure is total daily intake.

* Significant at 5% level.

** Significant at 1% level.

of either hay or grass, this being evident even in the absence of the apparent lowering effect of water intake on the specific gravities of centrifuged half-hour samples.

Conclusion

The effective buoyancy of rumen juice is less following the intake of fresh legumes than following the intake of either hay or fresh grass.

A COMPARISON OF TRUCKING AND TRAILING BEEF COWS AND CALVES TO AND FROM SUMMER RANGE [1]

FARRIS HUBBERT, JR.[2]

Squaw Butte-Harney Range and Livestock Experiment Station [3]

METHODS of moving beef cattle herds to and from seasonal range has received little controlled study in the Western range area. Trucking cattle between seasonal ranges has increased to some extent, and in general the conclusion has been that where trucking is possible it is a better method of moving beef herds than trailing. Ares (1942) refers to 15 percent shrinkage of cattle trailed 75 to 100 miles as compared to 5 percent shrinkage of animals trucked over the same route. Stoddard and Smith (1943) have cited the need for more information on the subject.

This study was designed to compare the influence of trucking and trailing beef cows and their calves to and from summer range on (1) response on summer range (2) shrinkage and weight fluctuations immediately following fall trailing (3) total gain from the time of leaving winter headquarters until the calves are weaned, and (4) response with and without a salt-cottonseed meal mix while on summer range.

Procedure

The study was initiated with a comparison of trucking and trailing 40 miles on the return to the valley from summer range during 1951. Forty cows with calves ranging in age from 6 to 7 months were assigned to the study from the herd of commercial Herefords maintained by the Squaw Butte-Harney Station. Twenty cows and their calves were selected at random to be trucked, the other twenty being trailed with the rest of the herd. Ten of the cows and calves assigned to each group had a salt-cottonseed meal mix available from approximately July 1 until the herd was removed from the range. The salt concentration of the mix was adjusted to a level that resulted in an intake of approxi-

[1] Approved for publication as technical paper 837 by the Director of Oregon Agricultural Experiment Station.

[2] Present address, Route 2, Kearney, Nebraska.

[3] Burns, Oregon. Jointly operated and financed by the Bureau of Land Management, U. S. Department of the Interior, and Oregon Agricultural Experiment Station. Oregon State College, Corvallis, Oregon.

mately 1 pound of cottonseed meal per day per cow during 1951. An intake of 2 pounds of cottonseed meal per day was allowed during 1952 and 1953.

Animals assigned to the study during 1952 and 1953 were selected in the same manner as was followed during 1951. Identical animals were not used during the 3-year period. Assignment to treatments during 1952 and 1953 was made prior to starting on the spring trail; the calves ranged in age from 1 to 5 weeks.

Spring Trail Conditions

The animals were trailed 40 miles from near Burns to the summer range during a 3-day period. At the end of each day's trail temporary corrals were set up where the calves were with their mothers overnight. The trailed cows' calves were hauled from one corral to the next during the spring trail. Water was available at frequent intervals. The cows were allowed to graze to some extent on new forage during the day.

The cows and calves to be trucked were hauled on the day the remainder of the herd started on the trail. This gave the hauled cows an advantage of 2 days of grazing on summer range.

Fall Trail Conditions

The animals were managed in the same manner during the fall on the return to winter headquarters with the exception that the trailed cows' calves were not hauled. Practically no forage was available on the fall trail. The herd had to travel approximately 14 miles between water holes on the second day of the trail during 1951 and 1952. The herd was bedded in a temporary corral without water at the end of a 10-mile drive on the second day during 1953 and was watered after a 4-mile drive the following morning. Maximum temperatures were close to 90° F. while trailing in 1951 and 1952 and below 80° F. in 1953.

Experimental Area

The summer grazing period was spent on sagebrush-bunchgrass range at the Squaw Butte unit of the station, located approximately 40 miles west of Burns where the elevation ranges from 4,600 to 5,000 feet. The animals grazed in fenced, 2,200-acre ranges composed primarily of big sagebrush (*Artemisia tridentata*) and bunchgrasses. Maximum summer temperatures seldom exceeded 90° F.

The fall grazing period was spent on the meadows of the station

located near Burns at an elevation of approximately 4,000 feet. The meadows are of the wet-land type with over 80 percent of the forage consisting of rush (*Juncus spp.*) and sedge (*Carex spp.*). Forage available during grazing was primarily mature stubble and scattered hay left in the haying operation.

Weighing Procedure

All weights were taken after the animals had been without feed and water overnight (approximately 12 hours). Calves remained with the cows during this shrinking period.

Initial spring weights were taken the day before starting on the trail. All animals were given an approximate 10-day fill on grass before the next weights were taken on summer range. Weights of all animals were then taken at approximate monthly intervals during the rest of the summer. The final summer range weights were taken the day prior to starting on the fall trail.

After arriving on the meadows all animals were allowed approximately 24 hours of rest and fill before being taken off feed and water and being weighed the following morning. Such a procedure resulted in the trucked animals being weighed 3 days and the trailed cows 5 days after the final range weights were taken to compare response during the trailing period. Both groups were then weighed at weekly intervals (first interval only 5 days for trailed group) for a 3-week period. The final weight was taken at weaning time.

Average daily gains for the periods involved were used in the analysis of variance of all data.

Results and Discussion

Spring Trail and Summer Range

Trucking resulted in significantly greater cow gains between the time the animals left winter headquarters and the time they were weighed on summer range (tables 1 and 2). The influence of trucking was also reflected in calf response during that period. Differences in both cow and calf response between years are believed to be related to differences in amount of forage available on summer range during the fill period.

Throughout the grazing season considerably more range forage was available in 1953 than in 1952. This difference was reflected in both cow and calf gains in all comparisons made between years while on summer range.

Trucking on the spring move was not found to influence significantly gains of cows after being weighed on summer range. Where differences in summer gains of calves were found, the advantages were in favor of the animals whose mothers were trucked (tables 1 and 2).

The low nutrient intake during the summer of 1952, resulting from less abundant range forage, is believed to have prevented the expression of the expected difference in growth potential between sex (table 1) reported by Knapp and Black (1941) and Koger and Knox (1945). The lack of a significant influence of sex on weaning weights of calves on low carrying capacity sagebrush range has previously been reported by Hubbert and Sawyer (1951). It follows that when the calf gains were high, as found in 1953, a significant difference in growth should be apparent between steers and heifers. Steers were found to gain significantly more than heifers during 1953 (table 1).

Fall Trail and Meadow Grazing

The gaining status and condition of the animals when coming off summer range had a great influence on response to the method used in moving to the valley. When the cows were losing weight and the calves were gaining at a reduced rate in 1952 trucking had practically no advantage in terms of weights at weaning. However, when the animals came off the range while still gaining, trucking had a significant influence on both cow and calf weights at weaning.

Data collected following the fall trail of 1951 and 1953 were used to study fluctuations in gains during the 3-week period immediately following removal from summer range. Results obtained during 1952 were not used in this comparison because the trailed herd was accidentally held without water for 12 hours after arriving on the meadow. It was believed that the long period without water would prevent a true measure of weight fluctuations immediately following the trail. The summer grazing season of 1951 was quite similar to that of 1952.

Fluctuations in gains during the 3-week period following fall trail are shown in figures 1 and 2. The trailed cows lost significantly more weight after reaching the meadow than the hauled cows only during 1953. In general, weight trends of calves followed those of the cows. The abnormal gains recorded during the first week on the meadow probably reflect fill in terms of excessive consumption of forage and water. The need for caution in the use of weights of beef cattle following periods of stress is emphasized by the abrupt fluctuations.

Trucking did not result in a significant advantage in cow or calf

TABLE 1. ANALYSIS OF VARIANCE OF AVERAGE DAILY GAINS OF COWS AND CALVES

		1952				1953			
		Cow		Calf		Cow		Calf	
Period	Source of Variation	d.f.	Mean Square	d.f.	Mean Square	d.f.	Mean Square	d.f.	Mean Square
Spring trail	Trucking	1	50.58**	1	0.47	1	29.53*	1	0.22
	Sex			1	0.01			1	0.69
	Supplementing	1	0.48	1	0.33	1	13.64	1	0.60
	Error	37	3.54	36	0.27	34	6.62	33	0.99
First month on range	Trucking	1	3.31	1	0.03	1	0.35	1	0.04
	Sex			1	0.00			1	0.28*
	Supplementing	1	0.00	1	0.01	1	1.08	1	0.18*
	Error	36	1.21	35	0.12	34	0.58	33	0.04
June to off range	Trucking	1	0.03	1	0.00	1	0.00	1	0.20*
	Sex			1	0.05			1	0.17*
	Supplementing	1	1.90**	1	0.33	1	0.31	1	0.49*
	Error	36	0.15	34	0.06	33	0.05	33	0.04
Off range to weaning	Trucking	1	0.45	1	0.09	1	2.43	1	0.52**
	Sex			1	0.07			1	0.45**
	Supplementing	1	0.45	1	0.39*	1	0.01	1	0.43**
	Error	36	0.52	32	0.09	33	0.31	33	0.05

* Significant at 5% level.
** Significant at 1% level.

weights at weaning in 1952. However, in 1953 trucked calves had a significant advantage in average daily gain of 0.14 pounds or an advantage in weaning weight of 27 pounds. The trucked cows also had a significant average advantage in daily gain of 0.08 pound or 16 pounds in total gain during the same period.

Whether trucking the breeding herd is economically sound would depend on many factors which would vary between ranches. The commercial trucking rate for hauling the cattle in this study was $0.23 per 100 pounds of body weight for the 40 miles. This would result in a total trucking cost of approximately $5.30 for the two trips per cow and calf.

TABLE 2. SUMMARY OF AVERAGE DAILY GAINS OF COWS AND CALVES

(Lb. per Day)

Period	1952			1953		
	Dates	Trucked	Trailed	Dates	Trucked	Trailed
			Cows			
Spring trail	4/29–5/13	1.00	—1.25	4/28–5/8	2.69	1.27
First month on range	5/13–6/3	2.51	3.10	5/8–6/12	0.89	0.67
June to off range	6/3–9/16	0.48	0.53	6/12–9/28	0.96	1.06
Off range to weaning	9/16–11/14	—0.12	—0.10	9/28–11/10	0.60	0.08
			Calves			
Spring trail	4/29–5/13	1.05	0.84	4/28–5/8	1.97	1.82
First month on range	5/13–6/3	1.64	1.59	5/8–6/12	1.67	1.61
June to off range	6/3–9/16	1.15	1.15	6/12–9/28	1.85	1.70
Off range to weaning	9/16–11/14	0.43	0.53	9/28–11/10	1.22	0.98

The salt-cottonseed meal mix provided during this study resulted in a significant advantage of 27 pounds in average weaning weights of calves for 1952 and 1953. No significant interactions between the supplementing and hauling treatments were found.

Summary

A study of the effects of trucking and trailing beef cows and their calves to and from a summer sagebrush range in eastern Oregon was conducted. The trail distance between winter headquarters and summer range was 40 miles.

Trucking resulted in no significant advantages in cow or calf weights at weaning following a summer when grazing conditions were poor.

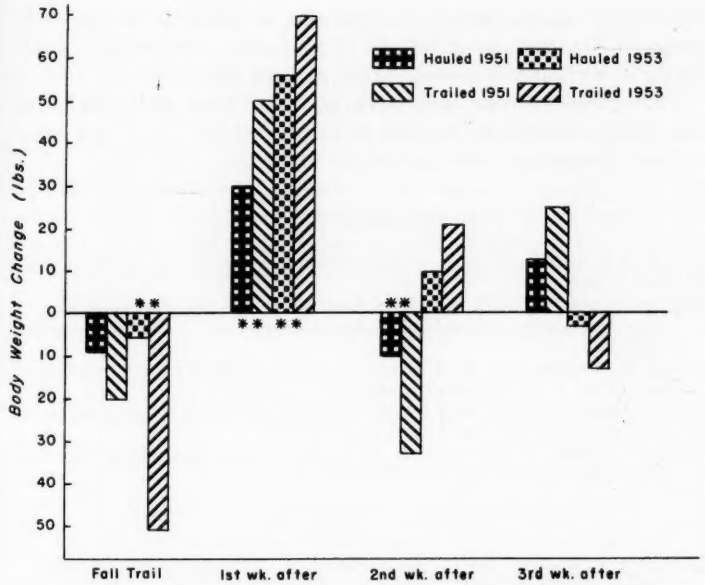

Figure 1. Summary of Cow Weight Changes After Fall Trail

** Significant at 1% level

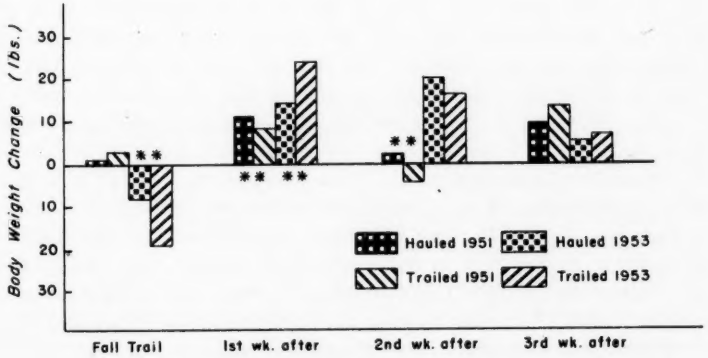

Figure 2. Summary of Calf Weight Changes After Fall Trail

** Significant at 1% level

However, trucking resulted in a significant advantage in average body weight of 27 pounds for calves and 16 pounds for cows at weaning following a good summer grazing season on sagebrush range.

Fluctuations in body weights during the 3-week period following fall trailing emphasized the need for caution in the use of beef cattle weights immediately following periods of stress.

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RECORD OF THE PROCEEDINGS OF THE FORTY-SIXTH ANNUAL MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

The forty-sixth annual meeting of the American Society of Animal Production was held in the Hotel Sherman, Chicago, Illinois, on November 26–27, 1954, and a dinner for the Honor Guest, L. A. Weaver, was held at the Stock Yards Inn on November 28. Abstracts of most of the papers presented were published in the November, 1954 issue of the JOURNAL OF ANIMAL SCIENCE, Vol. 13, pp. 955–1036.

PRESIDENT'S STATEMENT AT OPENING SESSION

A. E. DARLOW

President, American Society of Animal Production

May I extend greetings to each of you at this 46th meeting of the American Society of Animal Production, and if it is not within my province to extend greetings, since we are all affiliated with this organization, may I at least express to you appreciation for your presence.

We are meeting today and will meet tomorrow to discuss research, extension and teaching as it relates to animal production. We might spend considerable time looking back at the achievements and accomplishments of this group and congratulating ourselves and those who preceded us on a job well done. Actually, our morning program might indicate that that is what we plan to do. This is not the case, however. The thought of your officers as they planned this morning session, and I am sure each of you as you gather here, is not so much of what has been accomplished as it is of the opportunities of the future. This organization was conceived primarily as an organization where discussions of research work could take place. We are, in our opening program today, discussing the contributions that various segments of research work have made to the advancement of animal production and, in fact, to the advancement of our entire economy. As these contributions are recalled I am hopeful that the minds and imaginations of the listeners will not be stimulated to "back track" the devious paths

over which we have traveled, but rather that they will be stimulated to realize the almost unlimited opportunities of the future and, likewise stimulated to realize the rather awesome responsibilities which are ours.

True research and progress in the United States are almost synonymous. We have come in the past few years to the point where we almost deify research. Almost everything undertaken, even a very casual survey of consumer preference, travels under the canopy of research. I say again that true research and progress in the United States are synonymous, but I would remind you that it is not because research has been *done* but because research findings have been *put to work*.

So, as we gather at this 46th annual meeting I suggest the need to pause long enough to get research in proper perspective. We need to realize that progress depends on new information, new methods, new techniques; we need to realize at the same time, however, that this new information or these new methods or techniques contribute little or nothing to the general economy until they are put to use in production or commerce. If we may turn our attention for a moment to agricultural research we realize that the tremendous increase in agricultural production associated with a concurrently phenomenal decrease in farm population has been possible only because research has been at work. We know that these accomplishments of agriculture could not have resulted from research findings alone, but are actually the result of research information at work. This to me means, that when we discuss the contributions of agricultural research, we are in the same breath discussing the contributions of agricultural extension activities. The time between discovery and application has been greatly reduced. Why and how? Because we have available and working that uniquely American institution, Agricultural Extension Service. Then too, this Society concerns itself with teaching of subjects related to animal science. It may be difficult to point to one particular bit of teaching that has contributed as much as has one certain bit of research, but all of us recognize the fact that research workers become available only as the result of teaching. Research results become useful only as they are used in the classroom and by Agricultural Extension Service and private industry to improve production methods. To a large measure students become available to a college or university through their first contact with that college or university, and this in agriculture

is usually contact with the Extension Service. I am trying to point up the fact that it is impossible to separate teaching, extension and research when one is concerned with, or considering, the whole field of animal production. So, as we gather and discuss the contributions of research, let us each in his own mind relate these contributions not only to research but to the inspirational teachers who trained the research worker, and the inspirational leaders in the field who put the research workers' results and accomplishments to productive usefulness.

These three segments of production, teaching, research and extension, should not, and in fact cannot, be separated and walled off, one from the other. They are each a part of our total agricultural program. Just so, the worker in the field of agriculture cannot be separated or walled off from agricultural production or farming, nor can he be separated for long from the population as a whole. If there are among you those who are interested in and engaged in research only, or teaching or extension only, your obligation is not only to do a job in your field but to support vigorously, activities within the other two fields. An extension man will run out of "soap" in a hurry if research ceases to produce; research and extension will run out of manpower in a hurry if the teacher's functions falter.

All of these activities must operate within a changing society. Among the changes in our society that need to concern all of us is the progressive decrease in farming and agricultural population. The farmer is today truly a minority group. Now more than ever we must realize that we are working not for the farmer only, but that our contributions must benefit the whole of society. If we are to continue to deserve support of the public we need to recognize that the public is, to some extent, our partner in all of our undertakings, and no one of us is justified in assuming that a good job in any of the three fields is his sole responsibility. I don't want to suggest to you that we should cheapen our activities nor try to popularize them unduly, but I think it is the responsibility of each of us, in whatever field we are engaged, to call the attention of the citizenship continuously and constantly to the importance of work in our field and the contributions that it is making to the general advancement of all our people. I am trying to say in effect that agricultural education is *one* activity, and further, that it cannot and should not be insulated from society. So, it is the job of each of us to do the very best he can within the field where his

responsibilities lie, and likewise, to relate his work to all the other fields of agricultural production and in turn make known to all American citizens the contribution that agricultural education in general has made and the contributions that it can make in the future. We are in a large measure supported by public funds. We need to recognize that fact and realize that each of us has a responsibility not only to produce but to lend a hand in publicizing our contributions to society. Only thus can we continue to function to the fullest and continue to merit and receive the support necessary for that functioning.

ABSTRACTS OF ADDRESSES GIVEN AT THE OPENING SESSION

PROGRESS DEPENDS ON RESEARCH

R. M. Bethke

Ralston Purina Company

History shows that man began to make progress in supplying his material needs when he began to experiment—to try out things—to put questions to nature—that is to say when he began to do research. The idea held by ancient philosophers that an understanding of nature could be arrived at by processes of pure reasoning does not apply to the behavior of matter. The now generally accepted idea that progress depends on research is based on experience and requires no other proof.

Experience shows also that rate of progress depends on volume of research. This is beautifully illustrated by correlating data on the increase in number of research laboratories in the United States in the period 1920 to 1950 as shown in the bulletins of the National Research Council with the rise in the standard of living in the same period.

We frequently hear reference made to the "good old days"—implying that man fared better a generation or two ago than he does today. To me it is just a figure of speech which is meaningless—because I do not think that there is an individual in this audience who would want to lower his standard of living; get along without modern medical science—without modern systems of communications, modern methods of travel, present day methods of food processing and distribution, labor saving machines, and homes equipped with utilities and devices to make them comfortable and enjoyable. All this progress, most of which has occurred within the memory of most of us was possible because of research.

What has been accomplished in agriculture is truly extraordinary. When our forefathers began to create a new nation, nine people had to live on the land to feed themselves and one additional person in other pursuits. Fifty years ago (1904) a farm worker was able to produce enough food and fiber for 7 persons. By 1940, one farm worker could provide for 11 people—a 57 percent gain in labor efficiency in 36 years. Today, with more and better machines, a six-fold increase in fertilizer

use, improved crop varieties, better bred and fed livestock, and better weapons to fight insects, diseases, and weeds, one farm worker produces enough for about 18 persons. This is a gain of 63 percent in efficiency in 14 years. Workers-on-farms has declined almost steadily since 1910. The decline in the past 20 years has been particularly marked. From approximately 12¾ million in 1933–35 to about 8½ million in 1954 or a decline of 4½ million workers or around 33⅓ percent. Output per man-hour today is however about twice as great as it was 20 years ago. This, year by year, increased efficiency of American farmers has released workers to build our cities and to create our abundant non-agricultural industries and services from which agriculture is benefiting directly or indirectly.

Current estimates show that one-half of all manufacturing employment in the United States is based upon new products coming from research laboratories—as contrasted with only one-third in 1939. As a result, many business executives are just waking up to their dependence on research. This is why the big demand for innovation is directed at research.

Census Bureau projections show that we may have 200 million or more people by 1975. There is also a good possibility that dietary changes will occur because of further mechanization and nutritional education. This growth in population and change in diets will require a marked increase (60–75 percent) in total agricultural production.

The greatest challenge of agriculture of the future is to insure that food and fiber will be available at decreasing cost, with minimum strain upon our land resources, manpower, capital, and in accordance with the nutritional needs of the people. This means increased efficiency in all phases of agriculture.

If we are to continue to progress and meet the needs of the future, more and better research will be required. If research in the broadest sense is the answer then perhaps the most important questions facing us today are: How shall this needed research be managed? What proportion of our resources should be allotted to it? What lines or fields of research should be pushed? How should researchers be trained? What about basic or fundamental research versus applied research?

Effective research, in my estimation, can only result from an environment either in government or industry that gives the individual considerable freedom of thought and action and that is free from pressure. This is particularly true in case of fundamental or basic research.

However sympathetic management still has its place in such a set-up—if it's nothing more than safeguarding efficiency and the individual from acquiring or learning bad habits in conducting good research.

Much discussion has occurred within government and within industry on what proportion or percentage of the farm income and industrial income should be assigned for research. Comparisons have been made between the amounts appropriated by government (Federal and State) and the amounts budgeted by industry. I do not think that industry's expenditure for research and development is necessarily the proper yardstick for government to use. Neither do I think that industrial nor government expenditures should or can be a more or less fixed proportion or percentage of sales or farm income. Instead, I think appropriations in either industry or government should be based on need.

Similarly it is my opinion that it is not possible to divide or agree on what type or how much research should be done by private enterprise and by government. However, I do believe that much can be gained by establishing proper liaison between industry and government research workers on a subject matter or problem area basis.

The lines of research that should be pushed depend upon the area or individual problems which need an answer. Much can be gained by attacking problems on a cooperative rather than on an individual or local basis. Considerable progress has been made by government in this respect. In my opinion, it is a research management procedure which will expedite research and make for greater efficiency. The old adage that "the wheel that squeaks the loudest is the first to receive the grease" always has and probably always will apply in the line of research that will be pushed. I know it has occurred in industry and I have a suspicion, from past experience, that it might still apply in government. It should not be.

Adequately trained research workers are the first essential to an effective efficient program of research. The training of future research workers in the various phases of livestock production is your responsibility. How well you do the job will in a large measure determine how rapidly we will progress in the future. May I make this general comment. Some research trainers appear to assume that the more individuals they turn out the better their job. In short they are volume conscious rather than quality conscious. In my judgment quality must take precedent over quantity if we are to build a strong research organization for the future. Too often individuals who do not possess the necessary

basic essentials for a good research worker are encouraged to take advanced work and they become problems for their employer and for themselves, and families.

Basic or fundamental research has been the foundation of all of the really big advances in agriculture and other industries. If we are to look forward to continuing progress, it is essential that provisions be made for research in the fundamental sciences upon which all progress depends. Industry is moving in that direction. The increased appropriations for Agricultural Research and the establishment of the National Science Foundation should serve as stimuli to greater basic and applied research.

Research can be the most powerful tool in building a better agriculture and a more healthful and prosperous country. However, progress will not be automatic. We need to look ahead in our research and direct our energies toward the opportunities as well as the responsibilities.

ADVANCING THE LIVESTOCK INDUSTRY THROUGH RESEARCH IN GENETICS AND ANIMAL BREEDING

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Estimates from agricultural statistics reveal that both production per animal unit and crop yield per acre have increased greatly during the last 35 years. If we consider the period since 1935 when both began recovery from the drought years and improved practices began to be applied increasingly in both fields, production per animal unit has increased 30 percent and crop yield per acre 36 percent.

Beef cattle have been selected with success for early maturity and blockiness. They are marketed at younger ages now than even a quarter century ago. Carcass yield of the animals, and suitability of the cuts to the trade have improved—we now have less bone, and more meat. Rate of gain has been held or improved a little.

Average annual yield of milk has increased about 1700 lbs. and butter fat approximately 63 lbs. for all cows milked in the United States since 1906. Averages in tested herds have increased about 4000 lbs. in milk and more than 150 lbs. in butter fat.

Artificial breeding is being practiced extensively now with dairy cattle in the United States, and in a number of other countries. About 600,000 herds are being bred artificially. Approximately 1900 cows are being bred per bull in a year. Some sires have serviced more than 10,000 cows in a year. Methods of diluting and storing semen have been discovered which extend the service of bulls beyond numbers of cows thought possible a few years ago. Production is begin increased in many herds through artificial breeding.

Wool production per sheep in the United States increased about ⅓ pound, in the last 25 years. Prior to 1910, lambs gained about ⅓ lbs. daily. Many lamb feeding trials in the last few years show gains from about .45 to .50 pounds daily.

About 1915 hogs fed well weighed 200 pounds at 8–9 months of age, and required about 400 lbs. of feed per cwt gain. Twenty years later only 6 to 7 months and 380 lbs. of feed were required. During the last 10 years the age for 200 lbs. has been reduced to 5–5½ months, with many making that weight in less than 5 months, and doing it on 300 to 350 pounds of feed per cwt gain.

Ton litters at 6 months of age were set up about 25 years ago in some States as a goal in swine production. Now litters weighing 1 to 1½ tons are fairly common, and a few litters weigh more than 2½ tons at 6 months.

During the last 12 years 300 hog producers were honored in Iowa as Master Swine Producers on a basis of their records. Numbers of pigs farrowed per litter in these herds increased from 9.1–10.8, numbers marketed increased from 8.1–9.5 in that period. Rate of gain was maintained, possibly improved a little. That was accomplished, generally, by using crossbred sows of breeds which excel in pig production, mated usually to a boar of a third breed. (Except for the last 5–6 years linecross or "hybrid" boars were used in many of these herds.) The breeding practiced by those men, therefore, utilized hybrid vigor, which has proved to be of much economic importance in hog production. Similar records are being made in other States.

The Danes through the operation of testing stations and breeding centers for more than 40 years increased litter size in the Landrace from 10.6–11.7, and number weaned from 8.3 to 9.6 pigs per litter; feed required per 100 lbs. gain was reduced 1.65 lbs. per year, and rate of gain improved slightly. Carcass traits responded to selection particularly in the early years after 1924 when the plans of operation were reorganized. But most of the improvement in carcasses occurred in about 10–12 years.

A slight yearly increase in daily gain (.02 lbs.), and a yearly reduction of 1.8 pounds feed per 100 pounds gain occurred at Beltsville from 1939–1952 in herds under a plan of litter testing and selection, similar to that practiced in Denmark.

Egg production per hen in the United States increased about 84 percent in the last 40 years. A saving of one pound of feed per dozen eggs has occurred since about 1940, in high producing flocks the saving is about 1.7 pounds.

Production of broilers increased about 23 fold since 1935. In 1947 12½ weeks and 12.3 pounds of feed produced 3 pound broilers; in 1952 only 10 weeks and 10.2 pounds of feed produced 3 pound broilers.

The improvements in production mentioned for the different classes of animals are due to the interaction of improvements applied in breeding, feeding, management, disease control and herdsmanship. Each is an important link in a chain.

Improvements in breeding were achieved through specialization. Breeds are examples of specialization. This specialization in cattle

gave us strictly beef breeds and dairy breeds; in swine, bacon and fat type breeds; in sheep, wool and mutton breeds; in poultry, egg and meat breeds.

Genetic Principles

A few of the genetic principles we have learned, and which are being or can be applied in animal breeding include:

(1) Variations among offspring of known matings have baffled men through many centuries. It was not until Mendel's discovery became known in 1900 that these variaitons began to be understood. It is now clear that each parent transmits to each offspring a sample-half of its own inheritance, and that this sampling allows parents to transmit by chance, different samples of inheritance to each offspring.

(2) Variations observed in the various characters are numerous because many genes or character determiners affect a single character, genes differ as to dominance, and because of joint interactions between genes and the environment.

(3) Because of negative genetic correlation between some characters, improvement in one is accompanied by a loss in another. Maternal effects also complicate the expression of some characters.

(4) Definite advantages for some traits, usually result from crossing of breeds. These advantages are understood generally as being due to hybrid vigor, arising from a combination of genes more favorable for maximum expression of the traits, than prevailed in the parents. Hybrid vigor is of most importance in species with high reproductive rates—such as swine and poultry, but it is not to be overlooked in other classes of animals.

(5) We have not been able to get combinations of genes into any single breed, to make that one breed superior in all traits. The breeds, therefore, differ in the present averages of their performance traits. These differences usually are not large. But they are important. A large part of the difference in performance traits between breed averages is heritable, but the heritable part of differences between averages of individuals within a breed usually is small.

(6) Investigations in recent years show that the heritable portion of variation in several important traits is quite low. Studies of records obtained during the last 15 years with swine, in respect to selection practiced, and heritability of the characters, reveal that some performance traits respond less to selection than we believe they should. That result is not clear now.

(7) Crossing of improved stock with the wild type or with "scrubs," followed by 5 topcrosses and selection toward the improved type brings the stock essentially to the level of the improved type.

(8) A long period of evolution established the species in the wild state, adapted to the environment through which they were sifted by nature. We have changed and specialized the species. We have changed the environment more and faster than we have changed some of the species. In herds which have produced champions, and outstanding records otherwise, selections usually are made under a highly favorable environment. Dangers are recognized in

that practice—such as emergence of new diseases, changes in agricultural practice and changes in the demand or trade. But maximum performance is attained, only, under environment favorable to that end.

(9) Lastly, animal breeding has not advanced from the art to the scientific phase, as fast as plant breeding, nor as fast as animal feeding. But I believe we are entering a period when the science of breeding will be practiced more than is the case currently.

Suggestions

Much improvement has been made in animals by breaking up various species into specialized breeds and types, developing herds of the breeds which we call purebreds, and using sires from these herds in grading and crossing by the mass of livestock producers. We face the problem, however, of further improvement, particularly of characters which resist our efforts in selection. The question we must face squarely, is how can we continue, or speed improvement to keep animal production advancing as advances are made in other fields.

First of all, we must further improve the genetic value of the breeds. Second, we need to learn how to utilize breeds to get higher levels of performance from them than we are now getting. If incross, linecross, or "socalled hybrid' sires can do more for the commercial livestock producer than purebred sires, we must learn how to produce them, and how to use them. The question then becomes, how can we improve the genetic value of breeds and utilize them to greater advantage, with the greatest certainty, in the shortest time, and at the lowest cost commensurate with the results?

(1) We can extend application of testing procedures as a means of finding genetically superior individuals, in classes of animals where testing has not been used much, and improve testing where it has been applied generally, for some time. Testing should be explored thoroughly in pedigreed herds and flocks on farms, and at central points. There are opportunities in this for Breed Associations, breeders, and both experiment station and extension personnel.

When genetically superior individuals are found, they must be used to advance a herd in genetic value, or much of their potential genetic value is not realized. Therefore, we need to learn how to form, maintain, and use lines built from superior individuals when they are found. This means the use of inbreeding, in some manner to a greater extent and with more skill than heretofore. To extend this point, possibilities should be explored for further specialization with breeds, by breaking the breeds up into distinct lines—the breeds now represent distinct lines of a species. This approach is being explored now with swine, poultry, sheep and cattle. Results thus far are not sensational, but to me there is some evidence of encouragement. Research with artificial breeding may aid in this area.

(2) An alternative to breaking up breeds into inbred lines may be the forming of new breeds, that would be further specialization, extending a practice which led to one of the noteworthy achievements in the past. New breeds could increase the source of genetic variation between stocks. That appears to be important in crossing. A second alternative would be to utilize objective crossing of breeds followed by backcrossing to pick up genes which are needed to extend improvement of specific characters. That method is used effectively by plant breeders, and it was used by founders and early improvers of the breeds. These possibilities should be explored by experiment stations.

(3) Selection for improvement based on performance of crosses should be investigated, especially in poultry and swine. Trials are now in progress in that regard. Some tests are in progress with rats, mice and insects as the genetic material. Research is needed to uncover means of exploiting genetic possibilities not being used to the fullest extent in conventional practice.

(4) We must be alert to discoveries made with plants and small animals from the use of radiation, and other means of inducing variation, and be daring enough to try application of practices which may offer possibilities. We must learn how to cope more effectively with the hereditary mechanisms affecting performance of animals.

(5) Introduction of stock from other countries has been of tremendous importance in the past. It still may offer much in respect to further improvements. We should not be allergic to effort in that direction.

Finally, we must recognize that animal products are becoming increasingly competitive in the market place, not only with each other but also with substitute products. To maintain a favorable position in a competitive market usually requires improvements in the products, and increased efficiency in production.

Efforts on the part of breeders to improve the efficiency of animals in reproduction and as converters of grain and forage into meat, milk, eggs and wool probably have never been greater than at the present time. They need all the aid that research can bring to them.

Investigations as to methods of selection, and systems of breeding offer opportunity to us. We must be bold enough to investigate unorthodox practices, in search of methods that may advance the performance of animals, when we can no longer practice economically the methods now being followed. Further progress through breeding probably will require the breaking of new and uncertain ground. Such effort, however, usually is surrounded by debate and controversy.

As research men in the field of breeding, we must recognize the genetic aspects of the problems faced by the animal producers; direct our efforts toward discovering and developing methods which will aid breeders in advancing the genetic value of seed stock herds, and also aid commercial producers in increasing the efficiency of their practices.

BUILDING A GREATER LIVESTOCK INDUSTRY THROUGH NUTRITION RESEARCH

G. BOHSTEDT

University of Wisconsin

Human diets are rated good or bad, largely in the degree to which they do, or do not, include generous amounts of meat, milk, eggs, and fish. It is therefore cause for concern that the increase in the livestock population of the country lags greatly behind that of the human population. By the year 1975 the United States population is forecast to reach 200 million. Looking outside of the United States, at the present rate of increase in the human population, Latin-America according to some students of population, is to have 500 million people by the end of this century and therefore nearly double its present population. These forecasts appear to be backed by history, where the population of the planet is said to have doubled three successive times since the birth of Christ. It took 1650 years for the first doubling, from 300 million to 600 million. It then took only 200 years, until 1850, for the next doubling to 1.2 billion, but only 100 years since 1850 for the most recent doubling, to approximately 2.4 billion people.

Surpluses of grains and of cheese, or even animal fats including butter and lard, are not likely to be so menacing in the years to come. Even now many surpluses could be reduced or eliminated through proper advertising and merchandising of meat, milk, and eggs for their superior food value. A United States citizen, well-fed as to protein, therefore primarily animal protein, consumes according to Homer Davison of the American Meat Institute, the equivalent of 35 pounds corn, or 10 pounds corn plus 50 pounds hay. These feeds would be consumed by appropriate farm animals converting them to edible animal products that properly nourish a person one day while getting fruits, vegetables, and cereals in addition. Farm animals therefore are remarkable condensers of feeds into human food. We should as a nation like to enjoy a good diet indefinitely.

We owe much to the early scientists who developed a mere art of feeding into a science of nutrition, which in recent years is making effective use of research tools as provided by the atomic age. Early workers, going back a century and a half, concerned themselves successively with so-called "hay equivalents"; then gross chemical analyses;

later digestible nutrients; net energy values; and "true" versus "crude" protein. Much later they split protein into the constituent 22 amino acids, differentiating some of them as to their essentiality. Subsequently the 13 major and minor or trace minerals came under scrutiny. Meanwhile rapid advances affecting very intimately the health of man and beast were made in the discovery of vitamins, some 15 of them; and most recently remarkable effects upon gains and fattening of meat animals have been attributed to antibiotics and hormones as added to rations. It appears that the discovery of still newer principles of nutrition is constantly in the offing.

Looking years ahead and considering the increased amount of processing of feeds through industrial means, it becomes clear that there is danger to livestock and perhaps indirectly to man through the use of chemicals of one sort and another. Thus high-pressure lubricants containing highly chlorinated naphthalene and used in the machinery manufacturing or pelleting feed, have been proved to produce hyperkeratosis or X-disease in cattle. Extremely small amounts in the feed proved disastrous. Certain chemical solvents such as trichlorethylene have produced oil meals that were not safe to use. We do not yet have the answer as to what causes parakeratosis in pigs, but obviously nutrition is involved in this dreadful skin and systemic affliction. Many different compounds are used in insect and parasite control, which chemicals have a relationship to the health of livestock and to that of the consumer of animal products. Not only such materials, but different molds such as *Aspergillus clavatus* have been found toxic to farm animals. We grant that thousands of tons of moldy silage and hay or grain are fed without apparent harm to livestock, but we should be aware of the existence and possible spread of fungi that are not so harmless.

On the positive side, we have the challenging field of protein and amino acid supplementation which bids well to greatly reduce the necessary protein for critical animals. The addition of a single amino acid at times effects a considerable saving. We have not finished with carbohydrates and specific sugars, nor with fats and specific fatty acids, as very likely essential in nutrition.

The basic relationship of soil and climate to farm animals and to man commands increased attention. In view of the growing competition for the use of grains for human food, more stress might well be laid on pastures and forage crops that are adapted to their environment and that satisfactorily feed our livestock. This necessitates cooperative

investigational work as to their selection, their production, conservation and utilization.

The advent of antibiotics, trace minerals, and hormones, and the varying responses to them on the part of farm animals, makes desirable a more intensive study of the bacteriology of the digestive tract of not merely ruminants but also of monogastric animals.

Several nutrition committees under the auspices of the National Research Council, have worked earnestly in reference to recommended allowances of various nutrients in respect to energy, protein or amino acids, major and minor minerals, and vitamins. Their reports are studied by a widening circle of interested people on farms, in agricultural colleges and experiment stations, and in the feed industry. As more and more is found out about the nutrient requirements of farm animals fed for different purposes, more dependable recommendations will be forthcoming and which for greatest public benefit, should be widely disseminated.

Without pretending to be comprehensive about outlining a program of research in livestock nutrition, surely we are in agreement that we should do our utmost to promote an animal agriculture that has in its train so much that we find indispensable in our American way of life.

A SUMMARY OF THE MINUTES OF THE FORTY-SIXTH BUSINESS MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

W. M. BEESON, *Secretary*

Purdue University

The meeting was called to order in the Louis XVI Room of the Hotel Sherman, Chicago, Illinois, on November 27, 1954, at 2:30 p.m. by President A. E. Darlow. The minutes of the 1953 Business Meeting were not read but were approved as published in the JOURNAL OF ANIMAL SCIENCE, Vol. 13, No. 1, pp. 291–296.

The report of the Secretary was as follows:

"The American Society of Animal Production continues to grow in size with a total of 1344 members, which is an increase of 54 members over 1953. Members of the Society are scattered throughout the world with the following distribution: 1298 United States and Canada; and 46 Foreign. The membership committee and all members of the Society are to be commended on encouraging young men engaged in Animal Science to join this group. Through the work of this committee 150 new members have joined the Society this year. It has been my observation that there are many people who would like to become membrs who have not been asked. It should be the duty of each member to assume this responsibility.

"Subscriptions to the JOURNAL OF ANIMAL SCIENCE have increased slightly (12 more) with a total of 1012. In this total, 479 were domestic and 533 foreign. It is of special interest that the JOURNAL is sent to 49 different foreign countries. No doubt subscriptions to the JOURNAL could be increased by emphasizing the value of the scientific papers for people engaged in the many phases of Animal Agriculture. JOURNALS are being mailed quarterly to 2356 individuals, libraries and business firms.

"During the year the office of the secretary has sent three form letters to the entire membership and has mailed one or more letters to each subscriber. In response we have received about 4000 letters plus the usual personal correspondence necessary in the conduct of the business concerning the Society and the JOURNAL.

"Each year a larger percentage of research papers submitted are 'read by title' due to the fact that the time limit for our program is 'hemmed in' by Thanksgiving Holiday and Sunday in order to have the meeting concurrent with the International Livestock Exposition. This year 213 papers were submitted and we were able to accept only 141 to be given on the program due to time limitation. Many excellent papers were 'read by title.' Serious thought must be given by each member as to whether we should continue on this basis or, by some feasible modification, expand the time allotment for this meeting.

"Special tribute should be given to our retiring Editor, Dr. L. E. Casida, who has given freely of his time and ability to maintain a high standard in papers

published in the JOURNAL OF ANIMAL SCIENCE. Most people think it is a hard job to write a scientific paper, but it is a much tougher job to edit every paper that is submitted.

"In closing, I personally want to thank every member of the Society for their fine cooperation, and especially each committee member for the excellent job in organizing and conducting a stimulating program."

The treasurer's report showed that "the total assets in the Society funds on November 1, 1954 were $32,601.71. The balance for the General Society Fund shows an operating gain of $5,206.07 for the fiscal year. This year's net profit in the General Fund was less than last year by $1,388.65 which was due primarily to (1) an increase in the cost of the number of JOURNALS printed (400 more per issue) and (2) an increase in the expenses for the annual meeting ($400.00 more) on account of the requirement of employing slide operators for each section. Special acknowledgment is given to the Shearer Committee for giving the Society $284.90.

"Operating expenses for the Society are increasing each year. The total General Fund expenses for this year were $19,346.07, as compared to $16,817.37 for last year. The total income for the General Society Fund was $24,552.14. The income from the Morrison Award Fund was $1,656.53 and expenditures amounted to $1,479.50. The balance on hand in this Fund on November 1, 1954 was $2,827.23, showing a net gain of $177.03.

"The cash balance on hand in the General Fund at the close of the year was $14,841.48. In addition, the Society has assets of $7,000.00 in U. S. Government Bonds, Series E, $5,037.00 in U. S. Government Bonds, Series F, and $2,896.00 in U. S. Government Bonds, Series J.

"As Treasurer and Business Manager, I want to thank each member for his excellent cooperation in prompt payment of dues, arranging for reprint payments and for accurate notification of changes of address."

The Auditing Committee, consisting of H. M. Briggs, Chairman, R. H. Nelson and J. F. Lasley, made the following report, which was presented by R. H. Nelson:

"The Auditing Committee has examined the ledgers, deposit slips and bills paid by the Society for the year November 1, 1953 to November 1, 1954. The accounts were found to have been kept in a business-like manner, are accurate, and the Committee commends the Treasurer for the very efficient manner in which he has handled the fiscal details of the Society."

G. Bohstedt, Chairman of the Nominating Committee, proposed the names of J. I. Miller for President and W. M. Beeson for Secretary-Treasurer. These men were elected by unanimous vote. Nominees for

the Vice President were L. E. Casida and H. H. Cole. Ballots were distributed for voting on the Vice President.

President Darlow announced the coming retirement of L. E. Casida as Editor of the JOURNAL OF ANIMAL SCIENCE. The Executive Committee wishes to express the sincere thanks of the Society and to give special commendation to his excellent work. Also, the Executive Committee wishes to call attention to the great progress of the JOURNAL OF ANIMAL SCIENCE during his six years as editor.

The editor of the JOURNAL OF ANIMAL SCIENCE, L. E. Casida, gave the following report:

"A total of 1076 papers has been considered for publication in the JOURNAL OF ANIMAL SCIENCE from its beginning 13 years ago through November 15, 1954. Of these, 887 have been published.

"Publication during 1954 (Volume 13) included 112 papers, the president's address and other Society proceedings of the 1953 meeting (including memorials, awards, and committee and program chairmen for 1954), 200 abstracts of papers presented at the 1954 annual meeting of the Society, subject and author indexes of Volume 13 and the usual News and Notes Section in each of the four issues of the JOURNAL.

"Manuscripts received during the period from November 16, 1953 to November 15, 1954, totaled 142. Of these, 13 have been withdrawn or rejected, 66 have been published, 33 are in press to appear in the February 1955 issue, 9 are being revised by the authors and 21 are being reviewed by the Editorial Board. All papers on which editorial work had been completed at the time were sent to press for each of the four issues.

"Note should be taken of the fact that the 142 manuscripts received during 1954 exceeds by 15 the previous record number which was received during 1953.

"The terms of Wise Burroughs and I. W. Rupel on the Editorial Board expire December 31, 1954. The Executive Committee has appointed C. F. Huffman, S. W. Terrill and A. B. Chapman to the Editorial Board.

"Your Editor wishes to announce that he will retire from the Editorial Board as of December 31, 1954. He wishes to express his deepest appreciation to the various members of the Editorial Boards and of the Executive Committees during the past 6 years for their whole-hearted cooperation and willingness to help or carry responsibility. He wishes further to thank the membership of the Society for its patience with his efforts and willingness to overlook his errors. He would request the Society to extend the same courtesies to the incoming Editor and Associate Editor who will have a heavy load to carry in the years ahead.

"The Executive Committee announces the appointment of J. K. Loosli as the new Editor and W. D. Gallup as Associate Editor."

The records of the Business Manager of the JOURNAL OF ANIMAL SCIENCE listed the following back numbers of the JOURNAL available for sale:

Vol.	Year	Complete Volumes	Number of copies in single issues No. 1	No. 2	No. 3	No. 4
1	1942	0	0	1	2	18
2	1943	1	32	19	1	1
7	1948	0	0	0	6	0
8	1949	0	0	0	0	0
9	1950	0	0	0	62	64
10	1951	0	0	101	0	54
11	1952	0	0	0	88	148
12	1953	70	85	120	102	70
13	1954		348	370	388	390

These back numbers may be purchased from the Business Manager at the following rates: Volumes 10–13, $1.75 per single copy for domestic, and $2.00 for foreign; for preceding issues, $1.00 and $1.25, respectively. In addition, the following proceedings of the American Society of Animal Production may be purchased at a cost of $1.00 each for domestic and $1.25 each for foreign:

Year	No. of Copies	Year	No. of Copies
1915–16	48	1931	60
1922	446	1932	19
1923	229	1933	39
1925–26	39	1934	25
1927	46	1935	30
1928	1	1938	1
1929	30	1939	1
1930	16	1940	48

The following report of the Committee on Investigations was given by C. M. Kincaid:

"Three sections of the monograph on Research Methods and Techniques were completed prior to the last annual meeting. It is expected that the other two sections will be submitted in the near future and that the monograph will be in manuscript form and ready for publication during the coming year."

J. I. Miller reported that the Standing Committee on Membership had already submitted its report to the Society.

The report of the Committee on Information was given by Carl Neuman:

"News Releases covering a number of the reports presented at this meeting of the Society have already been sent to the four Chicago daily papers, the Chicago City News Bureau, and the three press wire services including the United Press, the Associated Press and the International News Service.

"News stories are also being mailed to the agricultural press of the nation

including livestock market papers, livestock and breed publications, including cattle, swine and sheep papers; farm papers, and papers of the meat trade.

"This report, however, must necessarily be devoted largely to the results of the Committee on Information's activities covering the 1953 meeting.

"It is well to remember, of course, that we do have access to all agricultural publications which receive stories. Following, however, are the papers which have come to our attention as using news releases sent out after the meeting last year.

"Beef cattle publications using news stories were the Gulf Coast Cattlemen, The Nebraska Cattleman, The American Hereford Journal, the Shorthorn World, the American Brahman Journal, the Southern Livestock Journal, The Cattleman, the Arizona Stockman, the Breeder Stockman and the California Livestock News.

"Market publications using copy included the Chicago Drovers Journal, the Omaha Daily Journal Stockman, the Kansas City Drovers' Telegram, the Denver Record Stockman, the South St. Paul Livestock Reporter, the St. Louis Livestock Reporter, the Oklahoma Live Stock News and the St. Joseph Missouri Stockyards Journal.

"News stories were used by two swine publications—The Poland China World and the Berkshire News.

"Meat trade publications devoting space to Society reports of last year included the Butchers' Advocate, the National Provisioner, the Meat Magazine and the New York City Retailers Bulletin.

"Stories were used by the following farm papers—Western Farm Life, Nebraska Farmer and the Colorado Rancher and Farmer. This makes a total of 27 agricultural papers in the states of Arizona, California, Colorado, Georgia, Illinois, Minnesota, Missouri, Nebraska, New York, Oklahoma, Texas and Virginia.

"In addition to these agricultural publications, the following papers used 1953 meeting news stories—Fresno, California Bee; Oskaloosa, Iowa Herald; Chicago, Illinois Tribune; Hays, Kansas News; Topeka, Kansas Capital; Batavia, New York News; Hornell, New York Tribune; Brookings, South Dakota Register and the Seattle, Washington Times.

"Two of these papers—the Chicago Tribune and the Seattle Times have a combined circulation of 1,162,000.

"Special mention should be made of the help rendered by Dr. L. E. Casida, and Dr. J. O. Grandstaff of this year's Information Committee, who were also on last year's Committee.

"The space devoted to the news stories by the publications mentioned totaled 653 column inches—which is the equivalent of 31 newspaper columns."

President Darlow expressed the appreciation of the Society for the excellent work that has been done by Carl Neuman and R. C. Pollock, the retiring Chairman.

W. P. Garrigus reported for the Necrology Committee and recommended that the following memorials be published in the JOURNAL OF ANIMAL SCIENCE: Walter Sewell Anderson, Warren Lale Blizzard, Edward Jonh Iddings, Lawrence C. Madison, Mark A. McCarty, Henry Perly Rusk, William Henry Tomhave. This report was accepted.

W. J. Loeffel gave the following report for the Resolutions Committee:

"That the officers and members of the American Society of Animal Production convey their sincere appreciation to Dr. and Mrs. F. B. Morrison for the continuance of the Morrison Award which has proved such an incentive to the members of this Society.

"That we also express to the American Feed Manufacturers Association our thanks for the continuance of their award which has also proved an inspiration to membership.

"That the Executive Committee express to the management of Hotel Sherman the thanks of the officers and members for the facilities provided for the 46th Annual Meeting of the Society.

"That the Executive Committee express to the officers of the Saddle and Sirloin Club the thanks of the membership for the privilege of holding its closing meeting, the Honor Banquet, in its historic halls."

Dr. T. C. Byerly submitted the following report as a representative to the American Association for the Advancement of Science:

"I attended the 1953 meeting of the American Association for the Advancement of Science in Boston. At that meeting, I participated with S. A. Asdell and L. A. Maynard of this Society in a symposium on food crops, our assignment covering food animals and animal foods. Dr. M. R. Irwin arranged the animal portion of the program and the papers have since been published in Science (Maynard) and Scientific Monthly (Asdell, Byerly).

"The 1954 meeting at Berkeley, the week of December 27, will include sessions arranged by the Association and by about 62 participating organizations. The Western Section of Soil Science is co-sponsoring symposia on Soil Management Problems in Western agriculture and on Water Supplies and Irrigation. Section O (Agriculture) is co-sponsor of a program on air pollution on December 30.

"An Arid Lands Conference will be held in Albuquerque and Socorro, New Mexico, April 26 to May 4, 1955, supported by UNESCO, National Science Foundation and Rockefeller Foundation. The meeting will include an open symposium.

"The 1955 meetings will be held in Atlanta and Dr. F. D. Keim, University of Nebraska, Secretary of Section O, has indicated his desire to stress Animal Industry, Conservation and Grasslands."

A motion was made, seconded and unanimously carried that the Society express its appreciation to Dr. Byerly for his efforts as representative to the AAAS.

A report on the activities of the Division of Biology and Agriculture of the National Research Council was given by J. O. Grandstaff, as follows:

"The third annual meeting of the Agricultural Research Institute was held jointly with the Agricultural Board on October 4 and 5 at the National Academy of Sciences. Attendance at this meeting included 31 Class A members, 33 Class B members, members of the Agricultural Board, and several guests. The pro-

gram this year was centered around the role of the ARI in relation to the National Research Council, National Science Foundation, State and Federal institutions and industry. There was also an excellent panel discussion on the subject of Industry-Government relations in agricultural research.

"Officers elected for next year were as follows:

President	H. E. O. Heineman, Pet Milk Company
Vice President	L. E. Clifcorn, Continental Can Company
Secretary	N. F. Kennedy, Corn Industry Research Foundation

"Present membership of the ARI includes 42 Class A members and 72 Class B members. Class A members are corporations whose business is concerned with agricultural products or research related to agriculture. Class B members include State and Federal research agencies and scientific societies.

"The Projects and Proposals Committee reported that it had again solicited all members of the ARI for suggestions which could be considered and translated into recommendations for the Agricultural Board. A total of 100 new suggestions was received, in addition to 54 proposals that were resubmitted from the previous year's list.

"Recommendations to the Agricultural Board included the following items of interest to the Society: The Committee noted that the problem of bloat continues to deserve major considerations and offered encouragement to the recently appointed Animal Health Subcommittee of the Board on bloat. It is further recommended that the Board consider the appointment of an ad hoc committee to study the need and organizational pattern for work on Animal Physiology and Metabolic Diseases.

"Several specific proposals related to Feed Adjuvants were received. It was recommended that these be forwarded to the Committee of the Board on Animal Nutrition for referral to the appropriate Subcommittees.

"Various proposals submitted by ARI members with reference to work in the area of Roughage Utilization and Preservation were recommended for attention of the Subcommittees on Beef and Dairy Cattle and Sheep.

"With reference to Feeding Practices and Nutrient Needs, the Committee recommended to the attention of the Board and its Committee on Animal Nutrition, a proposal for study on 'The influence of the nutrition of the dam on the viability and vigor of young animals and birds'.

"The Board's newly appointed Committee in the field of animal breeding was recommended for encouragement.

"The problem of Air Contaminants involving damage to plants and animals by fumes from industrial installations, was recommended for further study of the Agricultural Board.

"Among the several suggestions recommended for general consideration by the Agricultural Board were: (1) Proposals concerned with the Economics of Grassland Farming; (2) Urinary calculi in sheep and cattle."

Dr. Ralph W. Phillips, representing the European Association for Animal Production, gave a report of the activities for 1954 which was as follows:

"No new national associations have become members during 1954; hence the European Association for Animal Production still has as members the national associations for eighteen countries and territories; namely, Austria, Belgium, Denmark, Finland, France, Germany, Iran, Israel, Italy, Luxembourg, Morocco, the Netherlands, Spain, Switzerland, Tunisia, Turkey, United Kingdom and Yugoslavia. At the meeting of the Council of the Association in September 1954, the Academy of Science of Hungary applied for membership. The application was accepted and will take effect upon ratification by the Hungarian Authorities with regard to the membership fees.

"The financial position of the Association is sound, since all the member organizations have paid their subscriptions, thus enabling the Association to meet all its regular expenses and to set up a reserve fund.

"The Association continues to conduct its work primarily through the holding of study meetings, and through small commissions set up to deal with various aspects of animal production.

"The fourth in a series of study meetings was held in Lucerne, Switzerland, from September 25 to October 2, 1954, on the subject "The Influence of Climate on Animals and Animal Production." Four main papers were presented as follows: "The Influence of Tropical and Sub-Tropical Climate on Animal Production" by Douglas H. K. Lee, of FAO and Johns Hopkins University; "The Influence of Climate in High Altitudes on Animal Production" by H. Lortscher, J. Rieder and W. Morikofer, of Switzerland; "The Influence of Low Temperature on Animal Production" by J. W. Amschler, of Austria; and "Measuring the Effects of Managerial and Environmental Factors on Productivity in Animal Husbandry Research" by Ralph W. Phillips, of FAO. The last of these papers served to introduce a discussion of the possibilities of developing cooperation among countries and institutes in Europe in research in the field of animal climatology. Short papers were also submitted reporting on progress in this field in a number of European countries. The proceedings of this study meeting will be published by the Association.

"The Commissions, consisting in each case of workers prominent in the respective fields in the countries or most of the countries from which organizations are members of the Association, are giving attention to a number of topics. The Commission on Research is attempting to keep up to date a list of animal husbandry research stations in Europe, together with an indication of their major research projects, and is devoting some attention to breeding methods in beef cattle. A member of the Commission on Animal Nutrition has prepared a paper on the establishment of a standard method of measuring the nutritive values of feeds. Attention is also being given to investigations on the digestibility of feeds and to the use of antibiotics in animal feeding. The Commission on Horse Production is preparing a report on the present situation regarding horse production in Europe, and also maintains a calendar of exhibitions, races and horse shows in Europe. The Commission on Cattle Production has prepared the first draft of a paper on the organization of methods of keeping and operating herd books in Europe. A bibliographical list of important publications on cattle

production, which have been published in European countries, is being prepared. The Commission on Sheep Production is carrying out an inquiry on mutton production in Europe, and also one on the fat content of milk produced by various breeds of sheep. A paper is also being prepared regarding the number of animals necessary for progeny testing. The Commission on Pig Production is carrying out a survey, based on a questionnaire, of pig production and pig recording methods. Papers have been prepared on trends of prices for pigs in European markets, constitution in pigs, and hereditary factors in pigs.

"The association is also cooperating with FAO in the preparation of a glossary of animal production terms which, it is hoped, will eventually be available in four languages: English, French, German and Spanish. A drafting committee has already made considerable progress in the preparation of a first draft.

"The Council of the Association met in Lucerne, Switzerland, in September and agreed to undertake the following activities apart from those indicated above, during the coming year:

"a) the organization of a Fifth Study Meeting in Reading, England, in July 1955, on 'Animal Production from Grasslands';

"b) carrying out of preparatory work for the Seventh International Congress on Animal Production, which will take place in Spain in May 1956, and

"c) to participate jointly with FAO in the organization of a technical meeting on animal feeding problems in Europe."

Dr. M. L. Baker gave the following report as a representative of the Scientific Manpower Commission:

"The rapid scientific and technological developments of the past 15 years plus the demands upon manpower resources for military needs have focused attention upon our scientific manpower needs.

"In 1953, representatives of eight of the scientific societies of this country incorporated the Scientific Manpower Commission. Its purpose is to study the problems involved in recruitment, training and utilization of our scientific manpower resources.

"In cooperation with the Engineering Manpower Commission, the Manpower Commission of the American Chemical Society, it has given attention to our manpower problems.

"This past fall representation on the Commission was broadened to include two members representing six of the agricultural science societies through the Policy Committee of the Societies of Agricultural Science.

"The Commission has worked diligently with the ODM and Selective Service to clarify and improve selective service policies, especially with reference to graduate students.

"No doubt military manpower legislation to be introduced in the forthcoming Congress will command the close attention of the Commission."

President Darlow called for a report of the Tellers. This report, given by J. C. Miller, announced the election of L. E. Casida as Vice-President.

President Darlow introduced the new officers for the Society for 1955: J. I. Miller, President; L. E. Casida, Vice-President; W. M. Beeson, Secretary-Treasurer; J. K. Loosli, Editor.

Paul E. Howe suggested that the Society appoint a committee to "define the physical characteristics of the future beef animal." President Darlow reported that the Executive Committee had considered this recommendation and had placed this problem in the hands of the new Research Committee.

The meeting adjourned at 3:35 p.m.

MEMORIALS

WALTER SEWELL ANDERSON

Walter Sewell Anderson, Emeritus Professor of Genetics, University of Kentucky, died on October 8, 1954 at the age of 87 years. He was born in Academy, West Virginia on September 18, 1867.

He attended Randolph Macon College and was awarded the A.B. and A.M. degrees in 1896. In his senior year, he won three of the four medals then available for meritorious work at that institution. Years later, he studied at the Marine Biological Laboratory at Cold Spring Harbor, New York.

He served as Principal of the Alleghany Collegiate Institute at Alderson, West Virginia from 1896 to 1903. He then accepted a professorship in Biology at Kentucky Wesleyan College, Winchester, Kentucky. He served there from 1903 to 1913, at which time he was called to the University of Kentucky. He was one of the early Professors of Genetics in America, and he served in that capacity from 1913 to 1937 at which time he was given change of work status.

Professor Anderson was a teacher of great ability and he stimulated many of his students to proceed further along scholarly lines. Some of his students have advanced to positions of high professional standing. He was also an able investigator. His best known contribution concerned the inheritance of coat color in horses. He was also a great student of bloodlines in farm animals; and he was a pioneer in the microscopic study of spermatozoa in the general problem of sterility and reduced fertility in animals.

After his change of work status, he served as the Editor of publications of the Kentucky Agricultural Experiment Station from 1937 to 1942. He also did some sustitute teaching. In more recent years, he completed the studies on livestock history which he had started during his active period of teaching.

Professor Anderson was a member of Alpha Gamma Rho, Alpha Zeta, Sigma Xi and the University of Kentucky Research Club. He was listed in "American Men of Science," and for many years was a member of the Advisory Committee of the American Genetic Association. He was a highly respected citizen and was active in church, business and civic affairs. He was Chairman of the Fayette County School Board from 1925 to 1936 during which time several important school buildings were constructed.

Professor Anderson is survived by his widow and three sons. The latter are graduates of the University of Kentucky.

Professor Anderson lived a long and abundant life. His students and associates remember him for his commendable traits and faithful service to his University.

WARREN LALE BLIZZARD

Warren Lale Blizzard, dean of agriculture and director of the agricultural experiment station at Oklahoma A&M College, died on July 3, 1954 at his home in Stillwater, Oklahoma.

Born in modest circumstances on April 8, 1888, at McPherson, Kansas, he worked for a major part of his educational expenses at Kansas State College.

He was successively a farmer in Reno County, Kansas, assistant in animal husbandry at Kansas State, livestock fieldman for Capper Publications, and assistant extension livestockman at Iowa State College.

He joined the Oklahoma A&M animal husbandry staff on February 15, 1915, was made department head in 1919, and in 1943 became dean and director. He and Miss Alta Handlin of Manhattan, Kansas, were married in 1915, and this true helpmate survives him.

Diligent in all that he attempted, quiet yet friendly, Dean Blizzard will ever be an inspiration to his staff associates, the students, and the thousands of other people with whom he worked during his thirty-eight years in Oklahoma.

Versatile, he was a livestock judge of national and international repute, yet as an administrator he was skilled in selection of staff members, and as an educator he was apt in foreseeing the potentialities of the young people with whom he worked.

He helped fill, in a very special way, the needs of a state and a region that, compared with other agricultural sections, were young. He helped provide the leadership that resulted in the marked improvement of herds and flocks throughout Oklahoma and the Southwest.

He was a member of the American Society of Animal Production, and Alpha Zeta, and served for many years as a director of the American Royal Livestock Show and as president of the National Association of Stallion Enrollment Boards. He was a Scottish Rite Mason, Shriner, and Rotarian.

EDWARD JOHN IDDINGS

Edward John Iddings was born March 22, 1879 at Peru, Indiana and died October 22, 1954 in a hospital in Hemat, California where he had been confined following a heart attack one week earlier.

Dean Iddings grew up in his native state of Indiana and studied at Butler College from 1899 to 1901. Following his graduation from Colorado A. and M. College in 1907, he was appointed assistant to the dean of agriculture. He was appointed assistant in animal husbandry at Colorado A. and M. College in 1909 and in 1910 was called to the University of Idaho as principal of the school of practical agriculture and assistant in animal husbandry. This special pre-college division was established in 1910 for students not qualified to enter or not interested in the regular four year college curricula. A high school education not yet available in most of the smaller communities of the state, the division which he headed served an important need. He was appointed professor of animal husbandry at the University of Idaho in 1911. He became vice dean of the college of agriculture in 1913, dean of college of agriculture in 1915, dean of agriculture and director of the agricultural experiment station in 1918. In 1924 he was made director of extension and it was in his capacity as dean of agriculture, director of the experiment station and director of extension that he served Idaho agriculture until his retirement in 1946, at which time he was made dean of agriculture emeritus. He was further honored by the institution which he served so long and so well with an LLD in 1950.

Although his administrative responsibilities were most demanding of his time, Dean Iddings was the author of numerous bulletins and articles relating to live-

stock production and other agricultural subjects. His interest in and the promotion of improved breeding stock was a major factor in establishing the livestock industry in Idaho on a high plane. In 1916, shortly after he was made dean of agriculture and director of the agricultural experiment station, the University of Idaho was selected by the Suffolk Sheep Society of England to be the recipient of the first consignment of this breed of sheep to an agricultural college in western America.

Dean and Mrs. Iddings moved to California to live, following his retirement but they continued to maintain a keen interest in Idaho's agriculture and the youth who must be trained to serve it. In 1953 they provided $1000 for the establishment at the University of Idaho the Edward J. and Maude R. Iddings research fellowship in agriculture. Dean Iddings was a fellow of the American Association for the Advancement of Science, a member of the American Genetic Association, the American Society of Animal Production, Delta Tau Delta, Alpha Zeta, Sigma Xi and the Masonic Lodge.

Dean Iddings is survived by his wife, Mrs. Maude R. Iddings of San Jacinto, California.

LAWRENCE C. MADISON

Lawrence C. Madison, Professor Emeritus Animal Husbandry Extension, was born at Boone, Iowa, December 7, 1887. He graduated from the University of Illinois with a B.S. in Agriculture in 1918. He was married in April, 1913 to Lula E. Hutchison. They had one son, Lawrence Emery, and one daughter, Mary Elizabeth. He was a member of Alpha Zeta and Epsilon Sigma Phi. He first served as Field Representative of American Poland China Record Association. Later he became a member of the Animal Husbandry Extension Service, the Pennsylvania State University, in which capacity he served from February 1, 1924, to his retirement on July 1, 1953. He died at his home in State College, Pennsylvania, November 1, 1954.

MARK A. McCARTY

Born January 2, 1889, on a farm between Mapleton and Good Thunder, Minnesota. Mark received his early schooling at Mapleton, graduating from high school in the class of 1907 as valedictorian. Upon completion of his academic schooling, he taught a country school for a time at Truman, then continued his higher education at a business school in St. Paul, and then the University of Minnesota, receiving his Bachelor of Science degree with a major in animal husbandry in 1918.

Following graduation, he enlisted in the Army and upon discharge from the service at the end of the First World War, returned to the University of Minnesota as a member of the teaching staff in the Division of Animal Husbandry. There he taught for ten years and earned his Master's Degree. In 1930, he was offered a full professorship and head of the Swine Section at State College, Pennsylvania. Accepting the position, he remained there for fourteen years, teaching courses in breeds, pedigrees, herd-books, swine production and judging.

During World War II, he left State College to work as an economist in the Office of Price Administration, Washington, and upon close of that office,

he returned to teaching in the Veteran's Agricultural Training Program, from which he retired at Truman, Minnesota, on March 31, 1954.

During his career of teaching and breeding prize winning stock, Mr. McCarty won many distinctions for swine exhibits of his college at the International Livestock Exposition, Chicago. He was held in high esteem throughout the country for his very successful work in his field and was a valued contributor to agricultural publications.

In 1923, Mr. McCarty married Mary G. Flaherty of Minneapolis. After her death in 1933, he remained a widower.

Mark McCarty died June 2, 1954, near Cass Lake, Minnseota, where he was vacationing. Death was due to cerebral hemorrhage, which occurred while he was sleeping. He had no children. He was survived by two brothers and three sisters.

HENRY PERLY RUSK

Henry Perly Rusk, son of William Humphrey and Anna L. Renner Rusk, was born July 19, 1884, on a farm near Rantoul, Illinois. He was granted the B.S. degree from Valpariso University, Valpariso, Indiana, in 1904. The next year he enrolled at the University of Missouri where he became a member of its first livestock judging team to participate at the International Livestock Exposition. He also became a founding member of Farm House and later, 1920, served as its National President. He earned his B.S. in Agriculture in 1908 and the M.S. degree in 1911 from the University of Missouri. He married Edith Hartley of Eureka, Indiana, that same year. They have two daughters, Elizabeth and Martha.

His first college position was as Assistant in Animal Husbandry at the University of Missouri in 1908. The next year he joined the Purdue staff to take charge of beef cattle feeding research. In 1910 be became Assistant in Animal Husbandry at the University of Illinois, to begin a 42 year period of service to that institution. His successive promotions were: 1913 Assistant Professor and Assistant Chief of Cattle Husbandry, 1918 Professor and Chief in Cattle Husbandry, 1922 Head of Department of Animal Husbandry, 1939 Dean of College of Agriculture, Director of Agricultural Experiment Station and Extension Service in Agriculture and Home Economics. He retired on September 1, 1952. While his first and last loves were beef cattle production, his outstanding talents as an administrator and public servant led him to his greatest accomplishments.

A few of his more important assignments were: President of the American Society of Animal Production (1925–26); National Livestock Advisory Committee AFBF (1939); Agriculture Board NRC (1944–48); Board of Directors Farm Foundation ESCOP (1944–51); and Chairman Division of Agriculture (1949–51). Association of Land Grant Colleges and Universities; Chairman Committee on Agricultural Activities Hoover Commission (1948–49).

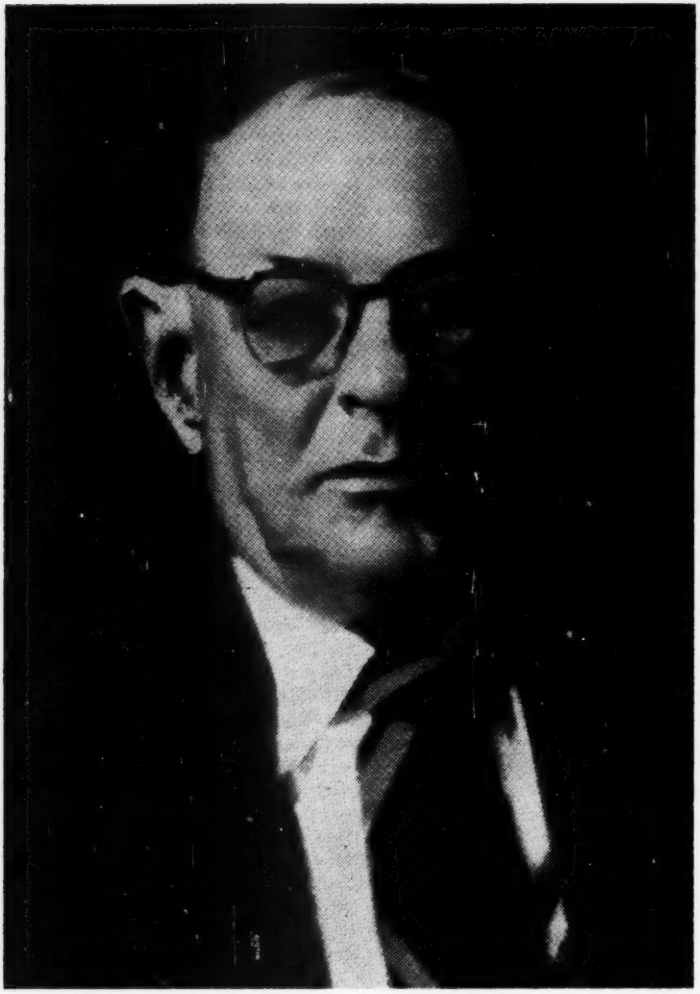
He was the recipient of many honors, one of which was being named as honor guest of the American Society of Animal Production in 1946 when his portrait was hung in the Saddle and Sirloin Club. He received the honorary degrees of Doctor of Science from Purdue University in 1949, Doctor of Science from the University of Missouri in 1950, and Doctor of Laws from Illinois Wesleyan University in 1951. The Distinguished Service Ruby was presented to him by Epsilon Sigma Phi in 1952.

Dean Rusk was a member of Alpha Gamma Rho, Farm House, Alpha Zeta, Gamma Sigma Delta, Sigma Xi, AAAS, ASAP, Illinois State Historical Society, American Planning and Civic Association, Urbana Rotary Club and the Methodist Church. Death came at Urbana, Illinois, on January 9, 1954.

In the passing of Henry Perly Rusk, the University of Illinois, his native State, and the Nation have lost a man of high professional attainment, sound judgment, and courage. We have all lost a friend—unselfish, sympathetic, understanding, and loyal. Although his active work has ended, his influence and inspiration will continue to live through his former students and associates.

WILLIAM HENRY TOMHAVE

William Henry Tomhave born Fergus Falls, Minnesota, December 19, 1881. Son of Peter and Minnie (Ladwig). Graduate of the Minnesota School of Agriculture, St. Paul, Minnesota, 1902; B.S.A., U. of Minnesota, 1907; M.S., Pennsylvania State College, 1908. He married Viola Edith Marsden, July 7, 1910; children—Viola Elna and Jeanne. Secretary, Northwestern Live Stock Show, S. St. Paul, Minnesota, summer of 1907. Assistant in Animal Husbandry, Pennsylvania State College, 1907–08. Livestock specialist for the Chinese government, Moukden, Manchuria, 1908–10. Livestock extension specialist, University of Minnesota, 1910–12. Head of department and professor of Animal Husbandry, Pennsylvania State College, 1912–25. National secretary of the American Aberdeen-Angus Breeders' Association, 1925–1946. Trustee and director of the Live Stock Department, Eastern States Exposition, Springfield, Massachusetts, 1917–1946. Director Society of Live Stock Records Association, Director and treasurer of the National Live Stock and Meat Board. Fellow A.A.A.S., Alpha Zeta, Gamma Sigma Delta, Chi Phi Men. Society of Animal Production. Portrait hung in Saddle and Sirloin Club, Chicago, Illinois. Mason, Republican, Presbyterian. Author: Meats and Meat Products, 1925; Brief History of Aberdeen-Angus Cattle, 1925. Contribution of articles for livestock and agricultural publications. Home address, 150 Le Grande Blvd., Aurora, Illinois. Died June 19, 1954.



L. A. WEAVER

Reproduction of a portrait presented to the Saddle and Sirloin Club in Chicago by the American Society of Animal Production on November 28, 1954. L. A. Weaver was the Honor Guest of the Socitey during its Annual Meeting which was being held at that time.

L. A. WEAVER

Honor Guest—1954

L. A. Weaver was born in Windsor, Mo. in 1886. He went to the University of Missouri in 1905 as a student in the College of Arts and Science. After his first year he changed into the college of Agriculture where he majored in animal husbandry. During the four years he was a student at the University he was on the 1909 livestock judging team, a member of Alpha Zeta, and a member of Sigma Xi. He was also a student assistant during the 1909–10 school year. He was married to Miss Sadie Gordon, a Christian College student, in 1912.

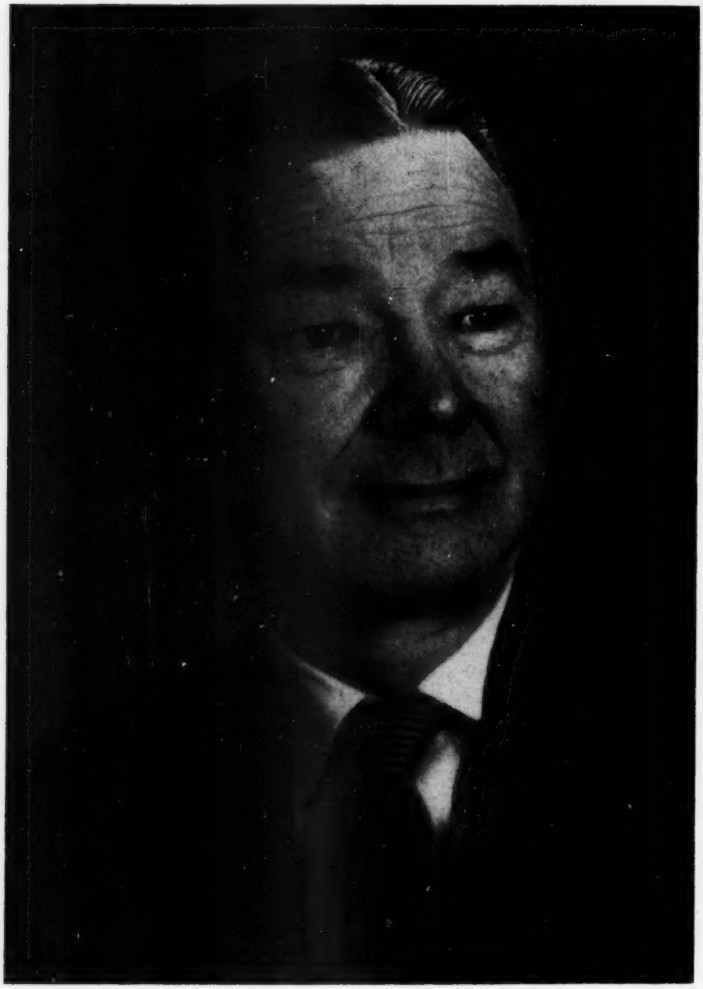
After graduating Professor Weaver stayed at the University as assistant professor in animal husbandry. In 1919 he was made full professor and was appointed chairman of the department in 1945.

Professor Weaver is well known for his extensive research in swine production and feeding. He is the author of numerous bulletins and circulars on the subject. During 1943 he was president of the American Society of Animal Production and is recognized as one of the leading swine specialists in the nation. He served as Superintendent of the Swine Department for the Missouri State Fair for many years.

Professor Weaver is known internationally as a swine judge. He has judged all breeds of swine at the International Livestock Exposition and has selected champion barrows at that Show more times than has any other single individual. He has participated in all of the major shows from coast to coast as judge of swine and beef cattle.

Professor Weaver is no exponent of theory alone. He owns and operates a 245 acre farm in Boone County, Missouri which serves to keep him familiar with everyday problems of livestock production and offers a practical field in which to apply research results.

Other honors achieved by Professor Weaver include being listed in "Who's Who in American Education" and "Who Knows—and What."



W. D. GALLUP

W. D. Gallup received the ninth Morrison Award which was presented during the 46th Annual Meeting of the American Society of Animal Production in Chicago on November 27, 1954.

THE MORRISON AWARD

1954

A willingness to undertake studes of a fundamental and long-time nature, and thereby contribute greatly to our knowledge of the basic facts of animal nutrition, has marked the research of the recipient of the Morrision Award for 1954. An examination of his records shows that he has been studying the carotene requirements of dairy cattle for nearly 18 years, that his research on the use of cottonseed meal in livestock rations has spanned more than 30 years, and that his contributions toward improving the utilization of non-protein nitrogen by ruminants have extended for more than a decade.

Willis Delancy Gallup was born in Clymer, New York, in 1899. He received his undergraduate training at the University of Buffalo and Washington State College, graduating from the latter institution in 1922 with a degree in Chemistry. That same year, he joined the staff of the Oklahoma Agricultural Experiment Station; and he has been associated with that institution throughout his entire research career. He received the M.S. Degree from Oklahoma A. and M. College in 1927, and the Ph.D. from Cornell University in 1937. Since 1940, he has been Professor in the Department of Agricultural Chemistry Research at Oklahoma A. and M. College.

Over 135 papers have been published by Dr. Gallup and his associates, dealing with a wide variety of fundamental problems in animal nutrition. Of singular importance is his work with cottonseed meal, especially his early studies on the nature and prevention of gossypol toxicity which did much to make this protein supplement a safe and useful feed. Other areas of interest have included carotene and vitamin A metabolism in cattle and sheep; the calcium, phosphorus and manganese requirements of cattle, sheep and poultry; factors influencing non-protein nitrogen utilization by ruminants; urea toxicity in cattle and sheep; and, on a broader basis, the digestibility of common feeds and factors affecting their protein and energy values. He is currently a member of 8 scientific organizations, and was appointed Assistant Editor of the JOURNAL OF ANIMAL SCIENCE in 1953.

Of greater personal pride than his many research accomplishments are his warm relationships with students and associates—and the high esteem with which he has been held by all who have worked with him during the 32 years of his active research career.

WISE BURROUGHS

Wise Burroughs was awarded the seventh American Feed Manufacturers' Association award, which was presented to him during the 46th Annual Meeting of the American Society of Animal Production in Chicago on November 27, 1954.

AMERICAN FEED MANUFACTURERS' ASSOCIATION AWARD

1954

Wise Burroughs was born in Tipton, Iowa, December 19, 1911. He was graduated from Blackburn Junior College in 1932, then received both his B.S. degree in Agriculture (1934) and his Ph.D. degree in Animal Nutrition (1939) from the University of Illinois.

He was assistant in Animal Husbandry at the University of Illinois from 1935 to 1939. From 1939 through 1944 he was assistant in Animal Industry at the Ohio Agricultural Experiment Station, and from 1945 through 1950 he was associate in Animal Science at the Ohio Agricultural Experiment Station and associate professor at Ohio State University. He is now a full professor on the Animal Husbandry Staff at the Iowa State College—where he has been since January 16, 1951.

Dr. Burroughs has done outstanding research, both fundamental and applied, in the field of ruminant nutrition. He was one of the pioneers in the use of rumen fistulated cattle and in the development of the artificial rumen—techniques that have enabled more rapid progress in ruminant nutrition. His research has involved studies on the nutritional requirements and physiology of rumen micro-flora, the utilization of low grade roughages and the application of hormones in cattle feeding. He has served as technical director for two motion pictures—one showing a gastric fistula operation and gastric motility and another on modern beef cattle nutrition.

His research reflects a keen perception of problems, careful planning and execution and conservative analysis and appraisal of the results obtained—all characteristics of a good scientist.

CHAIRMEN OF COMMITTEES, PROGRAM CHAIRMEN, AND SPECIAL ASSIGNMENTS FOR 1955

Standing Committees

Committee on Research.....L. E. Johnson
Committee on Monograph.....C. E. Terrill
Committee on Extension.....C. E. Bell, Jr.
Committee on Membership.....L. E. Casida
Committee on Teaching.....J. A. Hoefer

Special Committees

Committee on Information.....Carl Neuman
Committee on Necrology.....R. F. Cox
Committee on Nominations.....M. L. Baker
Committee on Morrison Award.....L. E. Casida
Committee on American Feed Manufacturers Award.....Damon Catron
Committee on Registration and Facilities.....W. M. Beeson

Program Committees

Breeding and Genetics.....H. H. Stonaker
Extension.....C. E. Bell, Jr.
Meats.....L. E. Walters
Nutrition.....T. S. Hamilton
Pastures and Forages.....R. J. Webb
Physiology.....V. R. Smith

Special Representatives

American Association for Advancement of Science Council.....T. C. Byerly
Committee on Intersociety Cooperation.....J. E. Foster
Division of Biology and Agriculture, National Research Council....J. O. Grandstaff
European Association for Animal Production.....R. W. Phillips
Ralston Purina Award Committee.....R. F. Cox
Scientific Manpower Commission.....M. L. Baker

NEWS AND NOTES

Applications for the Ralston-Purina research fellowship should be on file by March 1. Application blanks may be obtained from the Ralston-Purina Research Awards Committee in care of Mr. J. D. Sykes, Ralston-Purina Co., St. Louis, Missouri. The fellowships are for $1560 annually and awards will be made in the fields of nutrition and physiology research as applied to dairy, poultry, and animal husbandry, and in research in transmissible diseases of livestock and poultry. Individuals qualified for graduate study in any Land-Grant Agriculture College and approved Veterinary Colleges are eligible.

The Western Section of the American Society of Animal Production will hold its 1955 convention on the campus of the University of Wyoming, Laramie, from Sunday evening, July 10 through Tuesday, July 12, 1955.

The Biochemistry of Semen by T. Mann was published by John Wiley and Sons, Inc., New York, in November, 1954. The author has brought together and condensed the information on the chemical physiology of semen from an exceptionally wide range of publications.

W. W. Heinemann completed the Ph.D. degree in Animal Nutrition at Oregon State College in June, 1954. His present position is associate animal husbandman at the Washington State College Irrigation Experiment Station at Prosser.

Elements of Ecology by George L. Clarke was published by John Wiley and Sons, Inc., New York, in October, 1954. The book deals with the ecological interrelations of both plants and animals.

Genetic Homeostasis by I. Michael Lerner was published by John Wiley and Sons, Inc., New York, in December, 1954. The author undertakes to demonstrate that Mendelian populations possess self-regulating properties and also to establish a connection between genetic and developmental homeostasis. He suggests that heterozygosity provides a basis for both phenomena.

The second graduate summer session in statistics sponsored jointly by the University of Florida, North Carolina State College, Virginia Polytechnic Institute and the Southern Regional Educational Board will be held at Gainesville, Florida from June 20 to July 29, 1955. The total tuition fee will be $35 for the six-week term. The holder of a doctorate degree upon acceptance may register without the payment of any tuition fee. Full information may be obtained from Professor Herbert A. Meyer, Statistical Laboratory, University of Florida, Gainesville.

Dr. Kenneth R. Johnson has accepted a position on the staff of the Department of Dairy Husbandry of the University of Idaho, where he will be in charge of instruction and research in dairy cattle breeding.

Dr. Walter R. Harvey has accepted a position as Biometrician, in charge of Livestock Research Staff, Agricultural Research Services, U. S. Department of Agriculture, Beltsville, Maryland.

INFORMATION FOR CONTRIBUTORS

1. Papers may be submitted reporting work whose ultimate objective is clearly the solution of a livestock production problem and whose contents should be of interest particularly to those dealing with livestock production problems. Review papers on subjects of general interest will also be published at intervals, and will be prepared on invitation by the Editorial Board.

2. All papers will be subject to critical review by the Editorial Board, or others designated by the Editor. Papers needing revision will be returned to authors and should be revised and returned promptly. Papers not suitable for publication will be returned to authors with a statement of reasons for not accepting them.

3. Papers submitted should be based on new and adequate information. The following are guides to style and form:

   (a) Manuscripts must be typed, doubled-spaced, and the ribbon copy submitted.

   (b) Pages must be numbered. The lines of text must be numbered in the left margin, beginning with one at the top of each page. This does not apply to tabular material.

   (c) Tables should be as few and as simple as is feasible for presentation of the essential data.

   (d) Legend for each figure should be typed on a separate sheet. Photographs should be carefully prepared and labeled. Magnifications of photomicrographs should be indicated on legends. Charts should be prepared in India ink. Typed material on charts is not acceptable. Material that will not reproduce satisfactorily will be returned for revision. For suggestions on preparing illustrative material see the "Style Brief" published by the Wistar Institute Press, Philadelphia. If in doubt, consult the Editor before putting material in finished form.

   (e) The introduction should consist only of a paragraph indicating very briefly the nature of the question asked and the reason for asking it. Reference to relevant literature should be made later in the discussion of the results. Concise presentation of data is desired and there should be evidence of statistical examination wherever obviously useful in the interpretation. Unsupported hypotheses should be avoided. The organization of a manuscript may vary with the nature of the material, but all manuscripts should contain a clear statement of application of the results or their relation to some problem of the livestock industry. Each paper should end with a brief summary in the form of an abstract containing the most pertinent data in the briefest possible form.

   (f) Literature citations must be listed in alphabetical order and should be referred to in the text by author and date, i.e., Castle (1924), or (Castle, 1924). Citations may be referred to by number in review articles where the number of citations is too great to permit convenient use of the above form. "Literature cited" lists should be typed in a style used in a current issue of the JOURNAL.

4. Manuscripts will be edited in the order received, and accepted papers will be published as nearly in this order as feasible.

5. There will be a charge for making engravings in excess of one page per paper and of printing tables in excess of two pages per paper. The author will be asked when his manuscript is accepted to indicate the institution, agency or individual that will assume responsibility for the charges and for the reprints ordered at that time.

6. Authors will receive galley proof of articles together with a form for supplying an abstract for "Biological Abstracts". *Corrected proof and abstract should be mailed to the Editor within three days after they are received. Failure to do this may result in delay of publication until the next issue.*

7. One author of each manuscript should be a member of the Society. Papers by non-members can be published only after approval by the Executive Committee.

8. A "News and Notes" section will be published in each issue, including Society announcements, changes in positions and other items of professional interest concerning the members, and other items of interest to the membership. All such items should be sent promptly to the Editor.

9. Abstracts of papers to be presented at the annual meetings of the Society will be published in the November issue. Such abstracts must not exceed 250 words in length, should be typed (double spaced) and the ribbon copy submitted, the lines on the page should be numbered, in the left margin, from top to bottom, and must be in the hands of the Secretary of the Society by August 15, preceding the meeting. These abstracts must be summaries of results and conclusions.

10. Presentation of a paper at the annual meeting does not exclude it from publication in complete form in the JOURNAL. Such papers may be submitted to the Editor and will be given equal consideration with others submitted.

11. All manuscripts and correspondence concerning them should be addressed to the Editor: Dr. J. K. Loosli, Department of Animal Husbandry, Cornell University, Ithaca, New York, or to the publishers: Boyd Printing Company, 372–374 Broadway, Albany 7, New York.

12. All correspondence concerning subscriptions to the JOURNAL OF ANIMAL SCIENCE and other business matters should be addressed to the Business Manager, Dr. W. M. Beeson, Department of Animal Husbandry, Purdue University, Lafayette, Ind., or to the publishers, Boyd Printing Company, 372–374 Broadway, Albany 7, New York.